NASA CR 152208

(NASA-CR-152208) OPERATIONAL REQUIREMENTS FOR FLIGHT CONTROL AND NAVIGATION SYSTEMS FOR SHORT HAUL TRANSPORT AIRCRAFT (AVCON Aviation Consultants) 90 p HC A05/MF A01 CSCL 17G G3/04 N79-12054 Unclas 38853

Operational Requirements For Flight Control and Navigation Systems for Short Haul Transport Aircraft

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May 1978

Prepared Under Contract NAS 2-9028

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SUMMARY

This report presents several aspects of operational procedures for short haul and STOL aircraft. To provide a background for evaluating advanced STOL systems concepts, a number of short haul and STOL airline operations in the United States and one operation in Canada were studied.

A study of flight director operational procedures for an advanced STOL research airplane, the Augmented Wing Jet STOL Research Airplane, was conducted using the STOLAND simulation facility located at the Ames Research Center.

A flight experiment is proposed for use in the high air traffic region of the San Francisco bay area.

Finally, changes to the advanced digital flight control system (STOLAND) installed in the Augmentor Wing Airplane are proposed to improve the mode sequencing to simplify pilot procedures and reduce pilot workload.

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LIST OF ABREVIATIONS USED

ATC	Air Traffic Control
ATDZ	Above Touchdown Zone
CRT	Cathode Ray Tube
CTOL	Conventional Take-off and Landing
DH	Decision Height
EADI	Electronic Attitude Director Indicator
FAA	Federal Aviation Administration
G/S	Ground Speed
HOR/NAV	Horizontal Navigation
IAS	Indicated Air Speed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
Kts	Knots
MLS	Microwave Landing System
MSL	Mean Sea Level
NASA	National Aeronautics & Space Administration
N.M.	Nautical Mile
RFP	Reference Flight Path
RNAV	Area Navigation System
SAS	Stability Augmentation System
STOL	Short take-off and Landing
TDZ	Touchdown Zone
VFR	Visual Flight Rules
Wpt	Waypoint

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INTRODUCTION

AVCON, Aviation Consultants, Inc., submits this report under Modification 2 of Contract NAS2-9028.

The dimensional units used in this report are those currently used in the U.S. airline industry. The limited technical aspects of the work makes the use of metric units inappropriate.

This effort is the second year of the study of operational requirements for flight control and navigation systems for short haul transport aircraft. The first years work was reported in NASA CR-137975 dated November 1976. The areas reported were a study of curved path approaches currently flown by CTOL airplanes, an assumed Short Haul Transport route between downtown Boston and downtown Manhattan, and a simulator experiment of operational procedures for curved path approaches in auto flight.

This work includes interviews with local service airlines, a simulator experiment of curved path approaches using a manually flown flight director system, a suggested flight experiment for testing STOL operational procedures in an ATC environment, and some suggested mode select sequences of the STOLAND system.

RESULTS

Operational Experience of STOL Airplane and Short Haul Aircarrier Operations

The operational experience of current STOL airplane operations was gathered from eight short haul aircarriers. The only operators using an airplane in a STOL configuration were Airtransit, a temporary subsidary of Air Canada and Rocky Mountain Airways of Denver, Colorado.

The Airtransit experiment was an experimental commuter operation between two large population centers. The carrier operated from a small runway (2000') in a convenient location downtown to a similar runway in a similar convenient location in the other town. The experiment demonstrated that a downtown to downtown air transportation service is practical. Airtransit flights operated independant of and without interferance to the traffic of the local large airports. (See Appendix 2.)

Rocky Mountain Airways is still operating the DeHavilland Twin-Otter in a STOL configuration and has added the DEHavilland Dash 7 airplane to this operation. This operation is unique because of the high altitude airports and the one-runway operation of Aspen, Colorado. Summer weather produces take-off density altitudes of 14,000 feet for some of the airports and the tail wind take-off requirement at Aspen shows a real need for a STOL airplane.

The majority of the short haul carriers are airlines that use a relatively low performanee CTOL airplane to carry commuter and connecting passengers between large airports in high density traffic areas and medium size airports in low density traffic areas.

The majority of passengers using Short Haul air transportation are carried by airlines using airplanes like the B-737 and DC-9. These carriers sometimes find the airplane is performance limited at the smaller airports. (See Appendix 3)

The operational procedures and pilot techniques of the Short Haul transports are usually CTOL operations modified to operate out of the smaller airports.

SIMULATOR EXPERIMENT

An experiment was conducted on the NASA STOLAND Simulator using the operational concept, a similar reference flight path, and pilot procedures similar to those used by the short haul carriers (See Appendix 2 & 3). This experiment assessed the operational suitability of the STOLAND Flight Director system for flying a reference flight path involving a curved descent to a close-in final approach.

The STOLAND Flight Director System was found to be capable of directing the approach satisfactorily.

The approach flown had acceptable levels of system performance and pilot workload. The comparison which follows on the next 2 pages contrasts a Short Haul Transport Guidance System similar to the Collins FD 109 to the STOLAND Flight Director System.

The approach flown by airplanes in Short Haul transportation using a Flight Director is the standard ILS approach with a straight localizer and a glideslope of about 3^{o}. Rocky Mountain Airways flies a straight in MLS approach with a 6^{o} glideslope without a Flight Director.

COMPARISON

Short Haul Transport Guidance System	STOLAND Flight Director System
Speed and configuration management from cruise to final:	
55 to 100 knot change	75 knot change
easy to accomplish	easy to accomplish
requires frequency change	no frequency change required
must establish an intercept	waypoint to waypoint navigation
Approach path bank angles and turn rates:	
cannot fly 2500' turn radius IFR	same path IFR and VFR
cannot fly 180^{o} turn IFR	same turn IFR and VFR
15^{o}-30^{o} bank angles with high final approach	10^{o}-20^{o} bank angles with low final approach
Cockpit workload, IFR using Flight Director:	
moderate effort required	moderate to high effort required on "Basic" system
	moderate to low effort required on "Frontside" system
Levels of automation of Flight Director system:	
No display	CRT display of horizontal situation
simple switch, two axis command	complex switching, sophisticated command in an Electronic Attitude Director Indicator

Localizer capture using Flight Director:

frequency change required	auto tuned
must establish an intercept	localizer integrated into the final turn
fixed rate turn in	variable turn rate, initially hard to judge
alignment prior to descent	descent prior to alignment

Glideslope Capture using Flight Director:

3^0 glideslope	7^0 glideslope
fixed pitch change then deviation	must anticipate pitch rate difficult to repeat
easy task	moderately difficult task

Localizer Tracking using Flight Director :

moderate attention required	moderate attention required
cross-track error small	cross-track errors large during the final turn, small on final

Glideslope Tracking using Flight Director:

low attention required	moderate attention required except when using Backside or Frontside SAS then low attention is sufficent
vertical path errors small	vertical path errors small

Airspeed Management:

moderate attention required	moderate attention required
control primarily a trim function	elevator is the primary airspeed control and requires a lot of activity

Flight Path Profile

The Stoland Flight Director System was found to be operationally suitable for flying reference flight paths involving a curved descent to a close-in final approach.

The curved path approach shown in Figure 1., which is a 7^0 descending, 180^0 final turn with a 2500 foot radius, was operationally suitable in terms of bank angle, turn rate, deceleration distance and pilot work load.

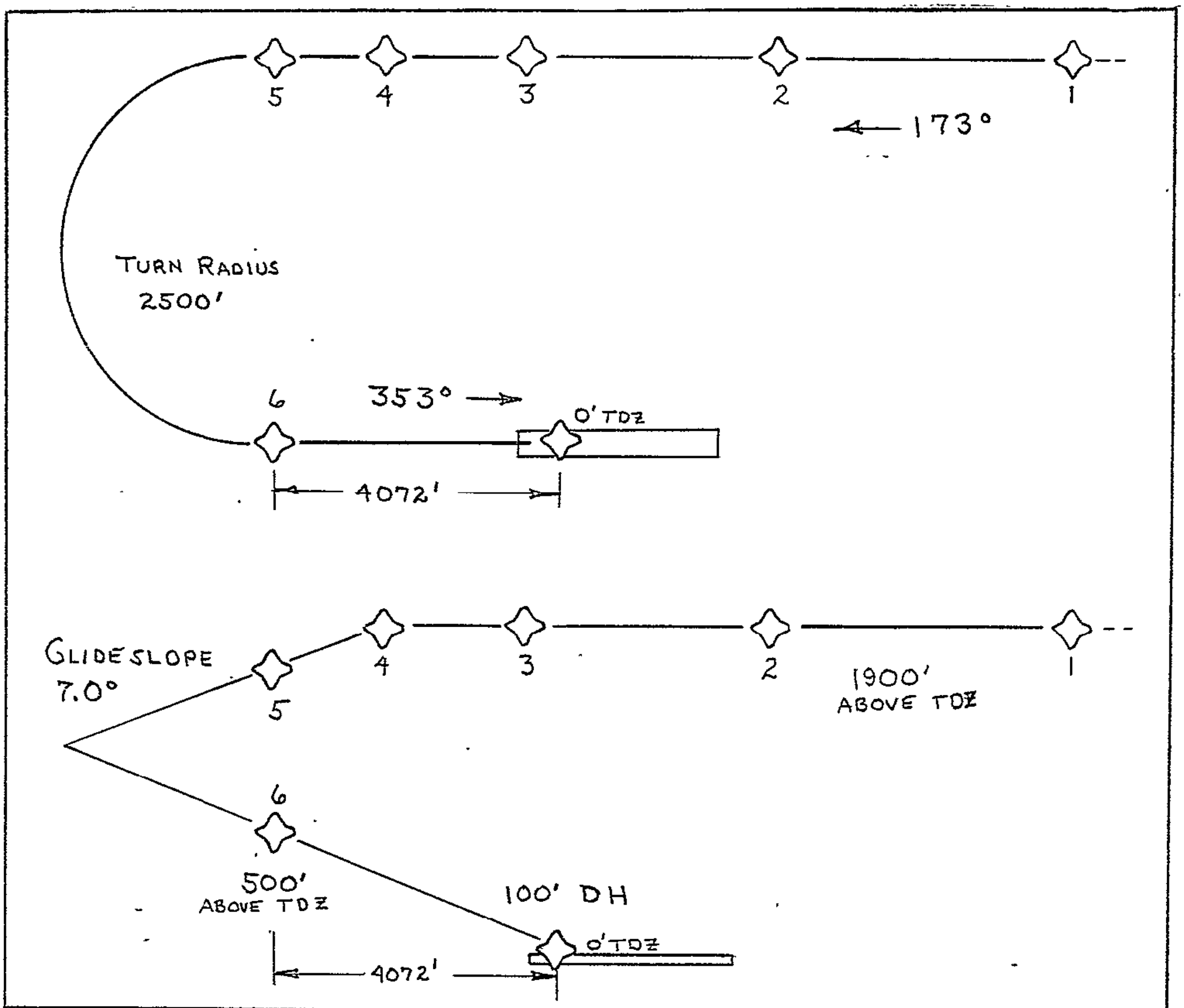


Figure 1.
Evaluation Flight Path Profile

Flight Procedures

The evaluation was made using a two pilot crew. The pilot at the controls was in command. The co-pilot monitored the airplane systems and provided support services upon command.

Prior to Waypoint 1.

The pilot maintains heading, airspeed and altitude so as to intercept the reference flight path prior to Waypoint 1.

The co-pilot tunes the navigation system, selects the flight director mode, the reference flight path and map display scale and orientation.

The airplane intercepts the 173^{o} course at 1900 feet above touchdown zone, 140 knots IAS with the landing gear down and the flaps up.

Waypoint 1 to Waypoint 2.

The pilot responds to flight director pitch, roll and throttle commands and calls for flaps 30.

The co-pilot selects flaps 30 and verifies the Mode Select Panel for Flight Director, IAS hold, Flight Path Hold, Altitude Hold, Heading Hold and the proper navigation facility selected.

The airplane follows course 173^{o}, maintains 1900 ft. ATDZ and slows to 120 kts.

Waypoint 2 to Waypoint 3.

The pilot calls for the flaps to be at 40, then 50.

The co-pilot selects flaps as requested.

The airplane follows course 173^{o}, maintains 1900 ft. ATDZ and slows to 85 kts.

Waypoint 3 to Waypoint 4.

The pilot responds to flight director commands to maintain stabilized flight. When the flight path deviation indication switches to the descent path, the pilot initiates a pitch down and deploys the nozzles (if on a manual path capture).

Waypoint 4 to Waypoint 5.

The pilot follows the flight director commands to transistion to the descending flight path.

Waypoint 5 to Waypoint 6.

The pilot follows the Flight Director commands as the final turn is started. The pilot calls for the final flaps to 65.

The co-pilot positions the flaps.

The airplane follows the curved, descending path and slows to the final approach speed.

Waypoint 6 to Waypoint 7.

The pilot follows the Flight Director commands in pitch, roll, throttle and nozzle.

The airplane rolls out on final approach and stabilizes on airspeed and rate of descent.

The evaluation ends at a decision height that is 100 ft. above the touchdown zone.

Flight Director

The Flight Director is assumed to be an operational system. It has three modes of operation that were evaluated during this experiment.

1. Basic attitude hold stability augumentation (Basic SAS)
2. Backside technique stability augumentation (Backside SAS)
3. Frontside technique stability augumentation (Frontside SAS)

The Basic SAS has an automatic elevator force trim function to neutralize elevator forces with airspeed change. This produces a mode similar to a control-wheel-steering autopilot mode.

The pitch command provides the primary control for airspeed by adjusting the airplanes pitch attitude during descent. There is a small contribution to vertical lift variation by the change in wing angle of attack as the pitch attitude changes.

The nozzle command is a trim function that moves very little during this mode. The nozzles do contribute to the vertical lift during descent in a similar manner to the flaps.

The throttle command provides the primary control for vertical lift by varying the thrust that is vectored by the flaps and the nozzles. The throttle has a secondary influence on airspeed.

The Backside SAS is a modification of the Basic System to provide automatic deployment and manipulation of the nozzles. This relieves the pilot of the responsibility of their operation, thus reducing pilot work load. It also keeps the nozzles in the proper position relative to pitch attitude and throttle position so that the secondary influence of throttle on airspeed is reduced and the secondary influence of pitch on vertical lift is reduced. The airplane appears to fly more directly like an airplane on the Backside-of-the-Power-Curve with airspeed responsive to pitch and vertical path responsive to throttle.

The Frontside SAS is a modification to the Backside system by providing automatic operation of the chokes. The chokes are devices designed to increase the effective response of the vertical lift of the flaps by varying the area of the outlets of the fan-stage air that is vented out the trailing edge of the flaps.

When the airplane pitch deviations are kept relatively small the throttle variations are small and this control is reduced to a trim function similar in movement to a CTOL throttle action during approach. Pilot work load is again reduced and the pilot,now being able to concentrate on pitch and roll, has a mode that appears to fly like a CTOL airplane on approach.

The roll command of all three modes is identical and directs the pilot to correct cross-track error.

Performance and Work Load

The modifications to the Basic SAS function only with flap and nozzle deployment. Therefore each mode of the Flight Director performed equally during the initial capture of the reference flight path up to the point of initial descent.

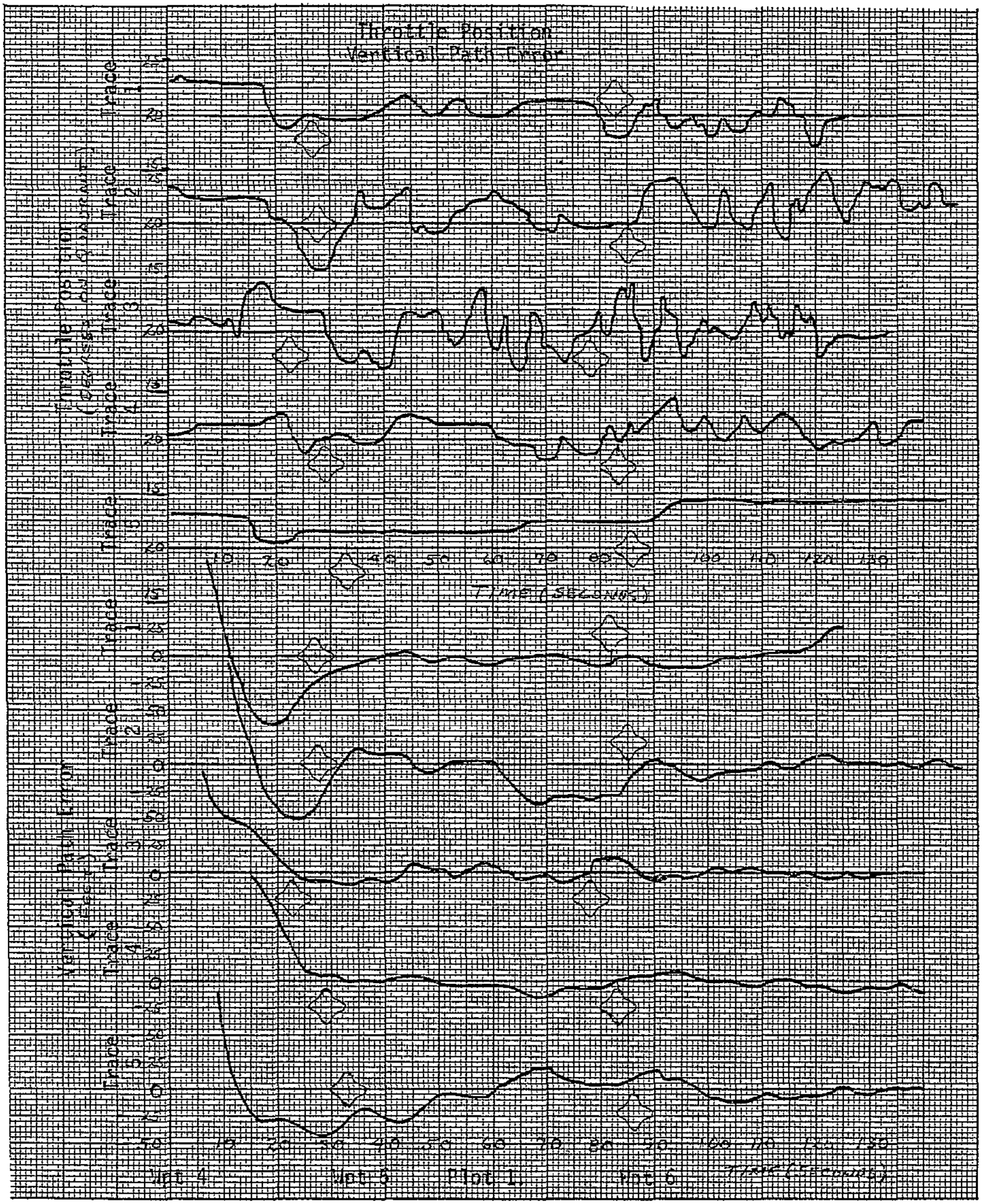
During the level portion of the approach the Flight Director appeared as adequate as those in present CTOL airline operation. The pilot sees sufficient sensitivity and damping in the commands to quickly and smoothly correct the airplanes flight path to the desired track.

The descending curved path provided a good task for the evaluation of each flight director mode.

Plots 1, 2 and 3 are time histories from Waypoint 4 to the approach decision height. Plot 1 is Throttle Position and Vertical Path Error. Plot 2 is Elevator Position and Airspeed. Plot 3 is Aileron Position and Cross Track Error. Waypoints 5 and 6 are marked on the plots.

The Basic SAS mode was adequate to fly the airplane on the curved path approach.

Trace 1 on Plot 1., shows the throttle activity. This activity is acceptable and just slightly more than would be expected during CTOL operations. The corresponding vertical path error indicates an over shoot of the descent path during the transistion from level flight between Waypoints 4



Throttle Position and Vertical Path Error vs Time

PLOT 1.

STOLAND FLIGHT DIRECTOR EVALUATION

October 1977

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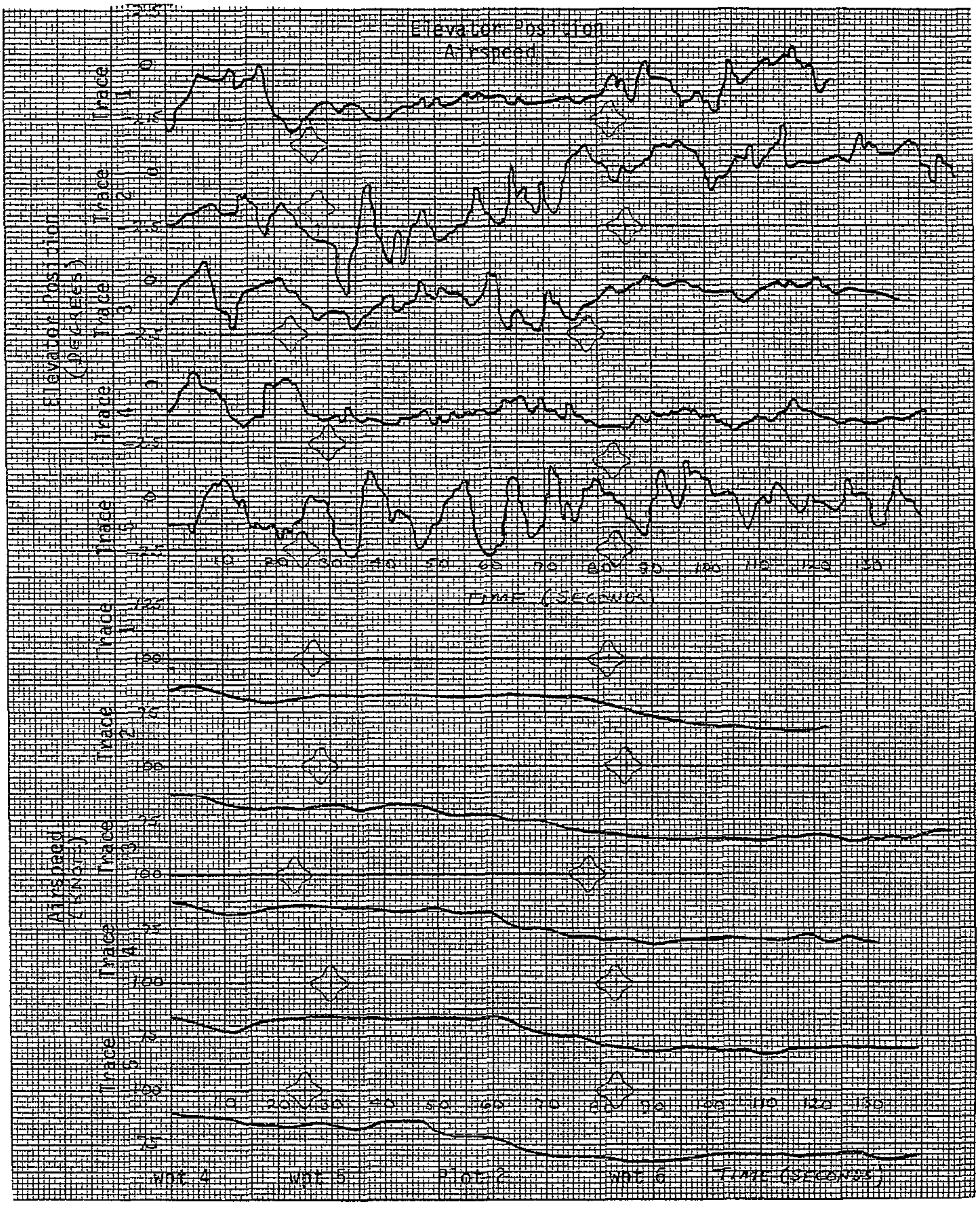

Elevator Position and Airspeed vs Time

PLOT 2.

STOLAND FLIGHT DIRECTOR EVALUATION

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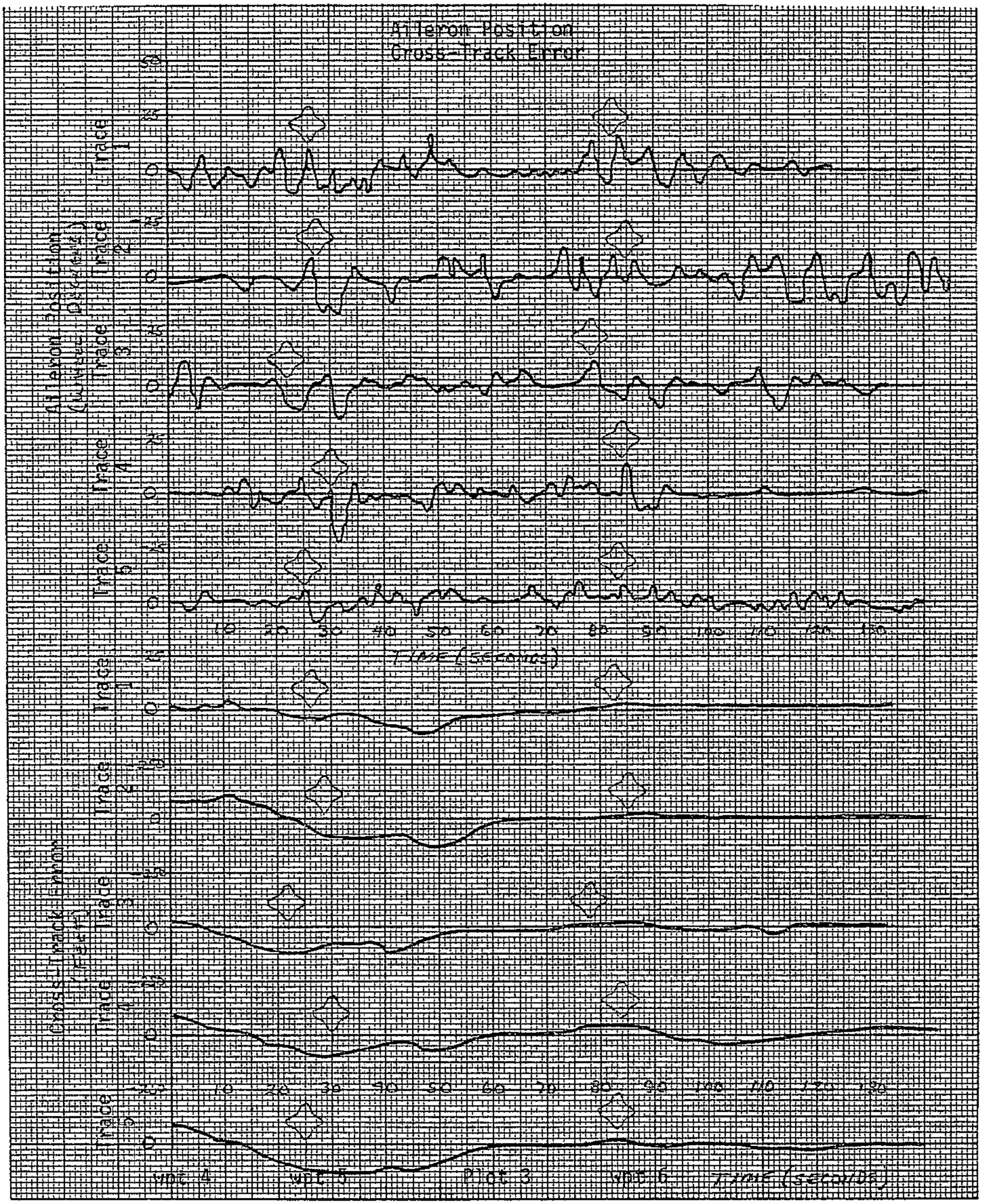


Aileron Position and Cross-Track Error vs Time

PLOT 3.

STOLAND FLIGHT DIRECTOR EVALUATION

October 1977

and 5. The vertical path is followed very closely during the descending turn and on the final approach.

Trace	Flight Director Mode	Test Conditions
1	Basic SAS	calm winds, manual transistion
2	Basic SAS	wind 308° at 15 kts turbulance = 3.0 ft/sec manual transistion
3	Backside SAS	wind 308° at 15 kts turbulance = 3.0 ft/sec manual transistion
4	Backside SAS	wind 308° at 15 kts turbulance = 3.0 ft/sec manual transistion, low sensitivity, deviation box on EADI
5	Frontside SAS	wind 308° at 15 kts turbulance = 3.0 ft/sec manual transistion, low sensitivity, deviation box on EADI

Table 1.

Trace 2 on Plot 1., shows an increase in throttle activity and consequently an increase in pilot workload. The Vertical Path Error has the same over shoot during the transisition and poorer path following during the final turn yet good path following on final approach. The change is produced by the wind and turbulance. The workload and performance is still satisfactory.

Trace 1 and 2 on Plot 2., shows the elevator activity increases with wind and turbulance while the airspeed performance remains relatively constant.

Trace 1 and 2 on Plot 3., shows the aileron activity and the cross track performance almost constant for both calm and windy conditions. The cross track error became large during the first half of the final turn. This characteristic occurred in all modes and flight conditions. The Flight Director didn't give sufficient lead to keep this error small during the first part of the turn but was very good at keeping the error small when the airplane was on the lateral path.

Wind and turbulance increased the pilots work load but not excessively. It also produced a small deterioration in performance but was still satisfactory. The difficulty of the transistion to the descending path is due in part to the absence of a programmed path for this change. Another contribution to the difficulty is the nozzle and throttle adjustments necessary during the transistion. The size of the movements are significant and very important to good vertical path control. These control movements require pilot attention at a critical time which increases pilot workload.

The lateral path following during the final turn could be improved by anticipating the turn.

In spite of these difficulties the overall impression of this Basic SAS Flight Director is that it is operationally sound in its ability to produce close tolerance approaches in localizer, glideslope and airspeed parameters during curved path approaches. The only question would be what minimums could the airplane be flown to using the Flight Director.

The Backside SAS made a good improvement in the Flight Director.

The addition of the automatic nozzle control to the system produced a remarkable reduction in the pilot effort required to follow the Flight Director, and an improvement in the airplane performance along the reference flight path.

The Backside SAS is the same as the Basic SAS until the auto nozzle control is activated. Therefore the approach is identical up to the capture and transistion to the descent path.

The pilot selects auto-nozzle at about the same point at which he made the nozzle adjustment during the transistion to the descent path. The work load can be reduced even further by enabling the auto nozzle and having the co-pilot activate the switch on request.

The absence of nozzle manipulation permits the pilot to concentrate on throttle and pitch control. Trace 3, Plot 1, shows a slight increase in throttle activity and a good improvement in vertical path error. The over shoot during transistion is nearly eliminated and the vertical path was tracked much closer.

Trace 3, Plot 2, shows a slight decrease in elevator activity and no change in airspeed performance.

Trace 3, Plot 3, shows a more significant decrease in aileron activity with no significant change in lateral path performance.

The Backside SAS produces an improvement in pilot workload and in vertical path tracking. The transistion is better and the pilot is able to follow the pitch and roll commands with smaller control movements.

With this improvement in the Flight Director it became obvious that the EADI deviation box was over sensitive for its position in the display. It moves around excessively and at times obscures the throttle command bar causing a delay in pilot response to throttle command. It also produces a slight illusion of pitch and roll command displacement causing small erroneous responses by the pilot. For further discussion of the EADI, see Appendix I.

Trace 4 on each plot is the Backside SAS with the sensitivity of the EADI deviation box reduced so as to keep it relatively stable on the EADI display. The improvement in the Flight Director is very apparent. Plot 1, shows a reduction in throttle activity and no deterioration of vertical path following. Plot 2, shows a major reduction in pitch activity and nearly constant performance in airspeed. Plot 3, shows a decrease in aileron activity and no apparent change in cross-track error.

When using the Backside SAS with a low sensitivity deviation box, the pilot's workload was greatly reduced and the Flight Director performance improved. The Flight Director was as easy to operate as some CTOL Category II Systems presently in airline service.

The Frontside SAS made a big change in pilot workload.

The Frontside SAS was implemented by adding the automatic function of the chokes to the airplane. This feature along with the automatic nozzle control made the pilot task very easy. The throttle command was reduced to a trim function with very little attention required on the part of the pilot.

Trace 5, Plot 1, shows the throttle activity reduced to a trim function with very little movement required. But, the vertical path error now shows a deterioration in vertical path following. With the EADI deviation box on Low Sensitivity this delay in performance is not apparent to the pilot.

Trace 5, Plot 2, shows the elevator activity to consist of large input at a slower frequency. The airspeed is still nearly constant and the pitch control appears now to influence vertical path error. This is how a CTOL airplane responds when flying on the Frontside-of-the-Power Curve.

Trace 5, Plot 3, shows small, frequent aileron imputs and the same cross-track error as previously observed.

The pitch and roll commands were very easy to follow and the system performance and pilot workload would lead one to believe that this Flight Director mode is as good if not better than CTOL Category II Flight Directors now in service.

The ease in flying this mode must be considered with respect to the reduction in path following performance. There is no doubt this mode is more pleasing to the pilot.

FLIGHT EXPERIMENTS

for testing

STOL Operational Procedures Along Terminal Curved Descending Flight Paths

The STOL Operational Procedures can be tested using the Bay Area as the operational area. If the experiment is conducted in weather conditions with at least a 5,000 foot ceiling and 5 miles visibility, then the procedures could be approved by Oakland Center and would not require formal application to or approval by the FAA.

The large jet aircraft traffic flow of the three major airports is depicted on Figure 2. The heavy arrows indicate the general traffic flow when San Francisco is landing on runway 28. The transistional altitude is 6,000 feet MSL in this area and the airplanes usually do not descend below 4,000 feet MSL until on the final approach course. The dotted line indicates experimental STOL traffic flow. The plan is to have the STOL airplane remain at 2,000 feet MSL until about 3 N.M. from the touchdown spot. The STOL descent would be a 7^{o} glide path that would curve to a short final about 3,000 feet from touchdown and about 400 feet above the runway.

The experiment would be a simulated commuter route that originates from Moffett Field and flys to the San Francisco, Oakland, and San Jose airports.

This simulated commuter route would provide a good test for the operational procedures by operating in a high density traffic area. San Francisco has very high density jet traffic. Oakland has slightly lower traffic density that has to be integrated with San Francisco's traffic. San Jose has high density traffic that is a mixture of commercial and general aviation airplanes.

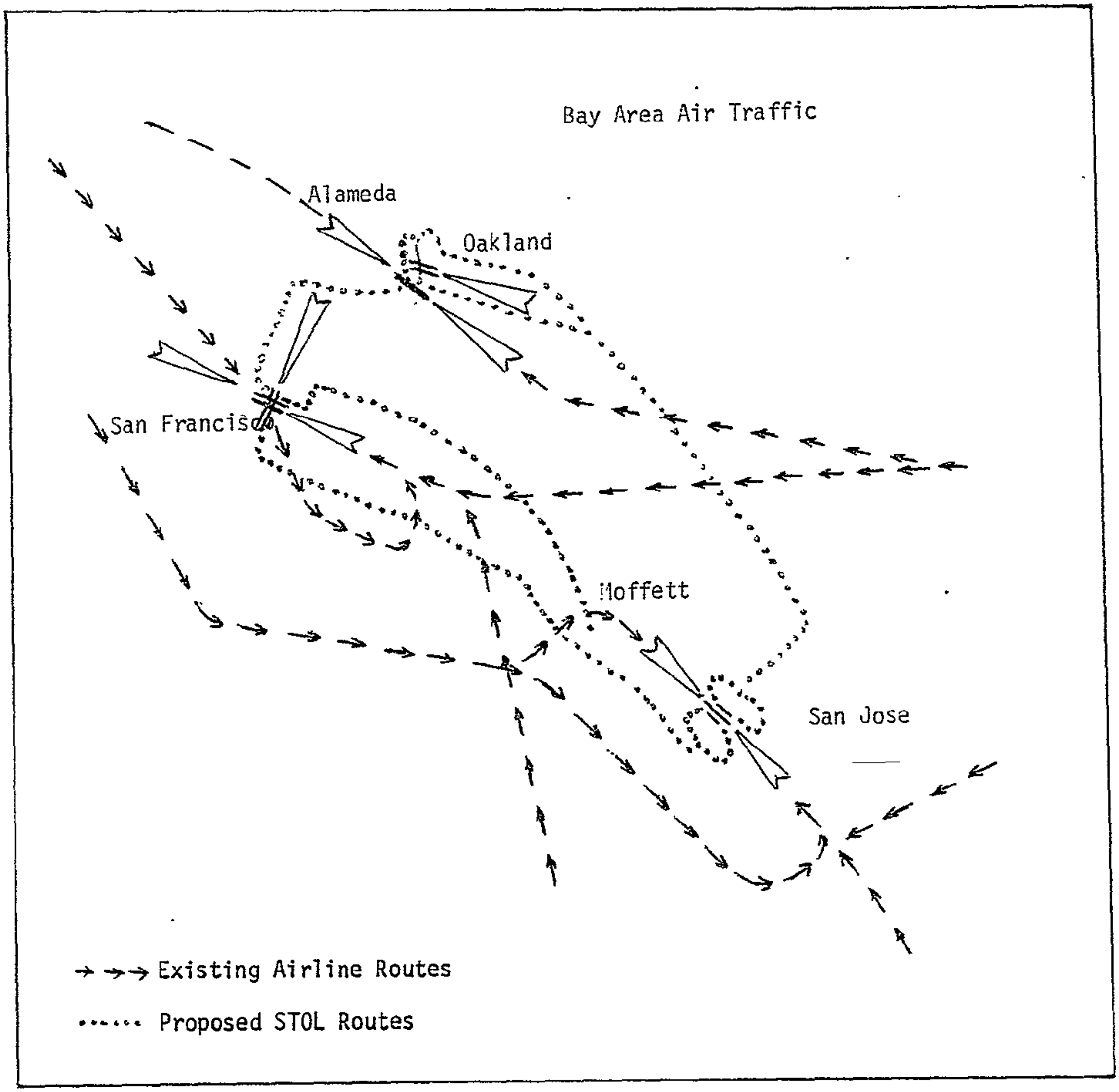


Figure 2
Bay Area Air Traffic

The experimental route would be flown both directions. The route schedule would be based upon the following estimated flight times between airports.

LEG	TIME (Minutes)
Moffett to San Francisco	12
San Francisco to Oakland	7
Oakland to San Jose	17
San Jose to Moffett	6

The ground time at each airport is assumed to be identical. An arrival and departure from a terminal gate will not be made. Ten minutes of ground time will be added to each leg for schedule purposes.

The following schedule assumes that the initial departure from Moffett field is at 10:00 pacific time on the test day.

DEPART TERMINAL		ARRIVE TERMINAL	
Moffett	10:00 a	San Francisco	10:12 a
San Francisco	10:22 a	Oakland	10:29 a
Oakland	10:39 a	San Jose	10:56 a
San Jose	11:06 a	Moffett	11:12 a

The approach to San Francisco International Airport has a 90^{0} turn in the curved descending path. The runways to be used will be Taxiway C between N and L which will be called STOL 28, and Taxiway L between M and G which will be called STOL 10 (Figure 3.) These STOL strips do not currently exist as such, but the described taxiways are sufficient to accomodate the landings. The choice of the STOL landing point adjacent to the primary runways is to provide for compatability with CTOL traffic. The approach paths are above the CTOL path and the touchdown spot is beyond the CTOL landing zone, thus the problem of the descending wake turbulance is avoided.

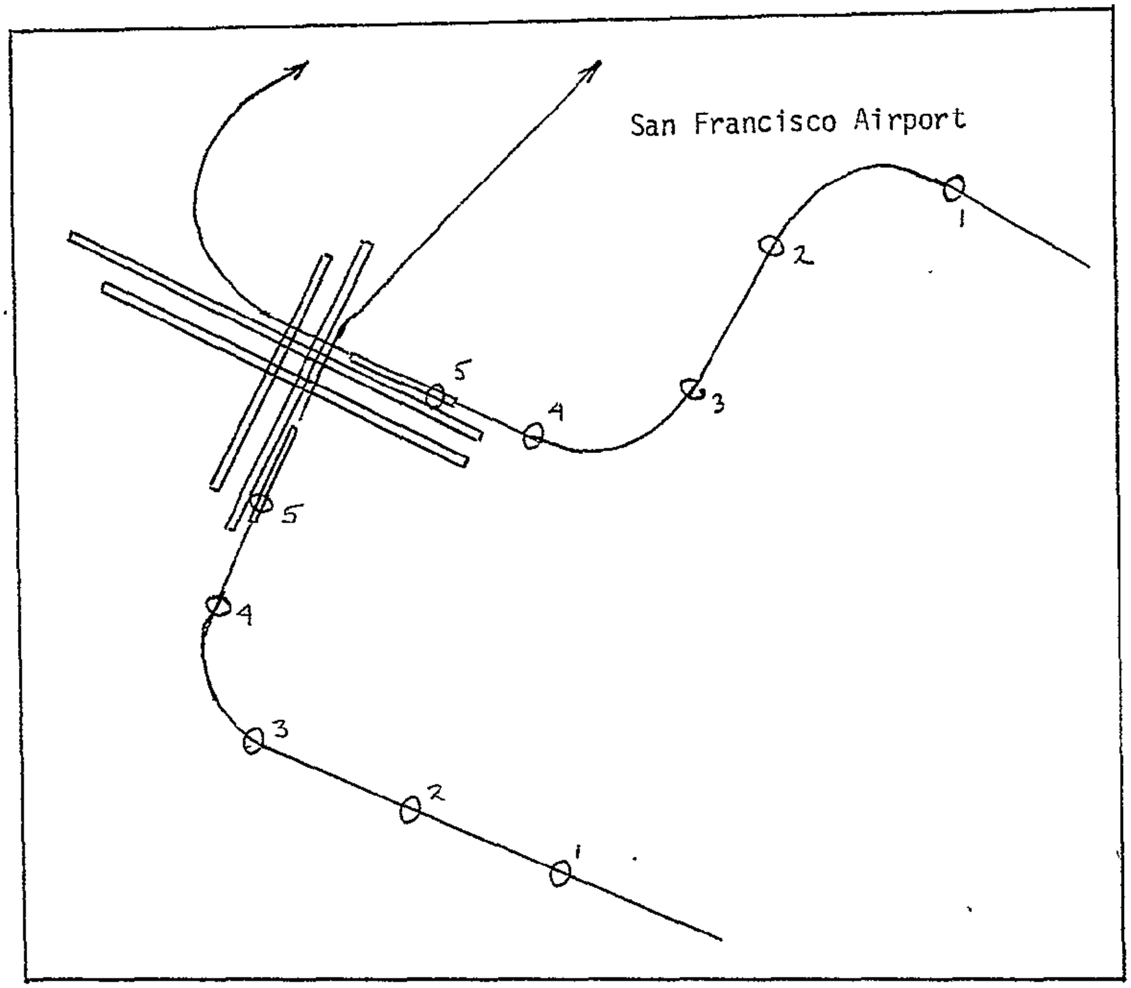


Figure 3
San Francisco Airport, STOL Routes

The flight path from departure to Waypoint 1. will be considered the enroute portion. This is to provide enough flexability to accomodate Air Traffic Control, the path from Waypoint 1 to touchdown will be programmed three dimensionally and flown in Autoflight or with Flight Director Command.

The path from Waypoint 1. to Waypoint 2. is the transistion from enroute to the terminal area. The descent will start at Waypoint 2. The turn will start at Waypoint 3. and the straight portion of the final approach will start at Waypoint 4.. Waypoint 5. is the glidepath intersection with the runway.

The approach to Oakland can either be the 90^{0} turn, curved descending path to runway 33, or the 180^{0} curved path to runway 15. In either case the initial altitude will be 2,000 feet MSL and arrival at the airport planned so as to cross over the long CTOL runway (Figure 4) The 90^{0} descending path crosses the center of runway 29 at about 1,000 feet MSL during the descent. The 180^{0}path approach crosses runway 29 while turning level at 2,000 feet MSL, the descent would start after this turn on the downwind leg. The 180^{0} turn to final would start about 1,575 feet MSL.

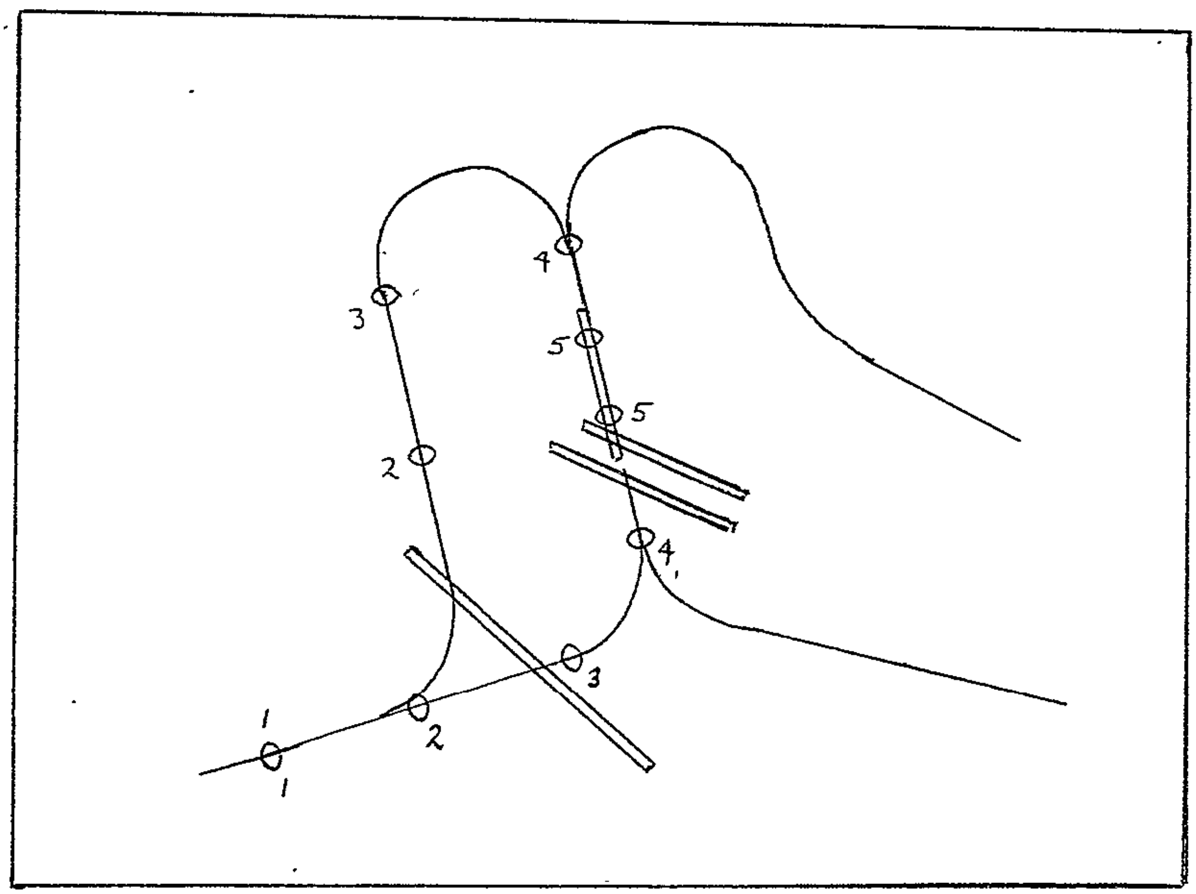


Figure 4
Oakland Airport STOL Routes

Both of the approaches to San Jose are 180^{0} descending turns to the short runways on each side of the airport. The approach on the East side would be to runway 30R-12L and the approach on the West side to runway 29-11 (Figure 5) The descent would start during the turn to the downwind and continue through the downwind, 180^{0} turn and final approach.

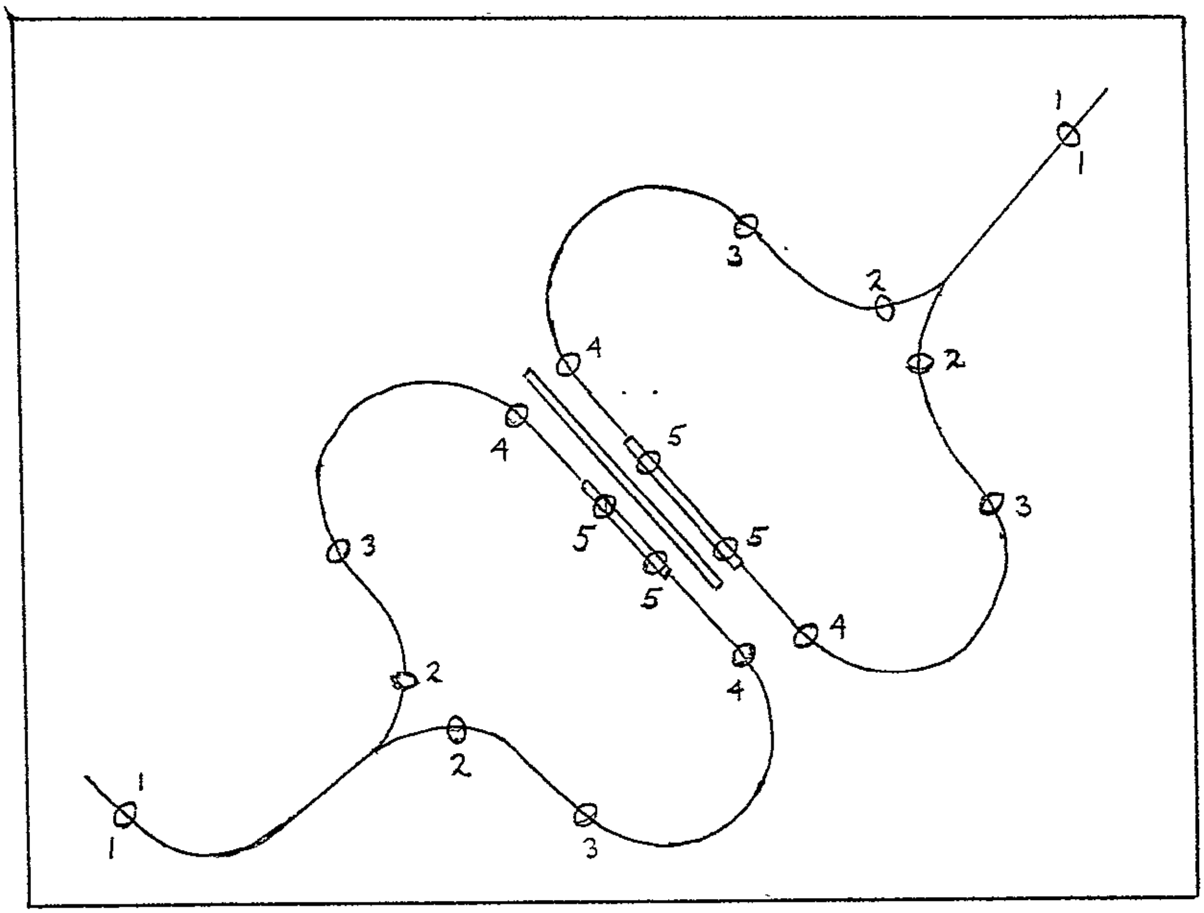


Figure 5
San Jose Airport STOL Routes

Each of the Bay Area airports will have a slightly different approach for the STOL airplane. The points in common in these approaches are, 1.) the airplane does not have to align with the primary CTOL runway, and, 2.) the curved descending path is kept in close to the airport in a traffic free area.

The Flight Prodedure for all airports will be as follows:

a) Two-pilot crew simulating IFR.

b) ATC vectoring by Bay Control to Waypoint 1.

c) Transistion to landing configuration between Waypoint 1. and Waypoint 2.

d) Descend on glidepath starting at Waypoint 2.

e) Initiate the curved portion of the approach at Waypoint 3.

f) Roll out on a short final approach at Waypoint 4.

g) Land in minimum distance.

h) Taxi to departure runway.

i) Take off, climb, get Bay Control vectoring to the next airport.

The detail design of the approach path can be easily tailored to the STOLAND-equipped Twin-Otter, or any of the Thrust Augmented Lift Wing type airplanes.

This project could be a pilot opinion exercise and an air traffic control study that would be evaluated with present on board data systems and the Bay Area Radar Systems. The navigation errors of such a test would not be determined due to lack of accurate tracking radar. The operational value of this project would not be significantly reduced by the deficiency.

SUGGESTED MODE SELECT SEQUENCES OF THE STOLAND SYSTEM

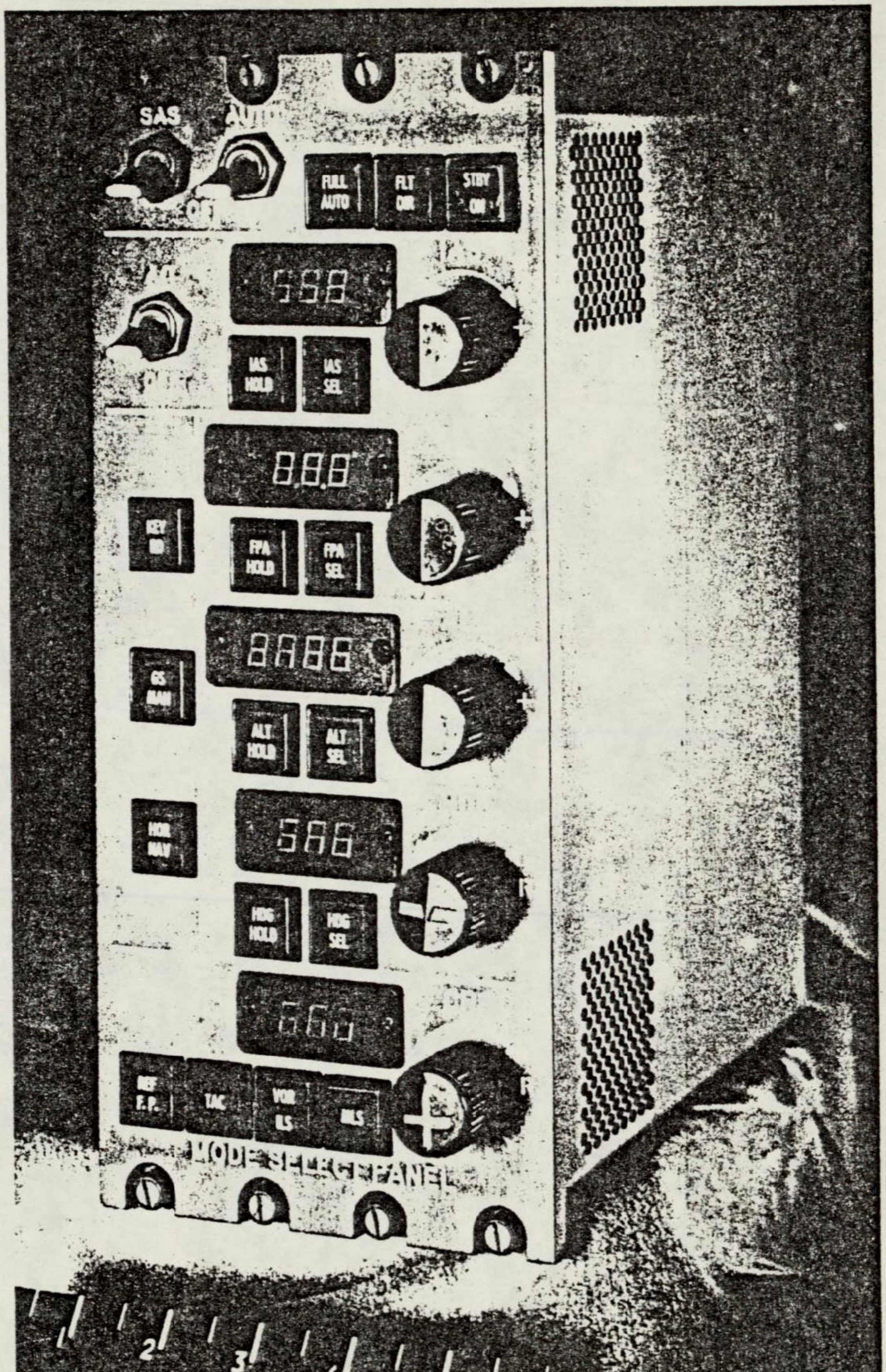
The test procedures used during the simulator evaluation of the STOLAND Flight Director System would be very difficult to use in an operational airline environment. There are too many selections required for easy flight management.

The basic requirements for a good operational flight guidance system are: a directional and logical order of sequences, command functions that are suited to the handling qualities of the aircraft and easy to operate.

The existing STOLAND hardware system could be made to work like an operational system during flight simulation if it were programmed such that the various modes could be pre-selected prior to flight. Then there would be very little need for further manipulation of the switches and knobs once flight has begun.

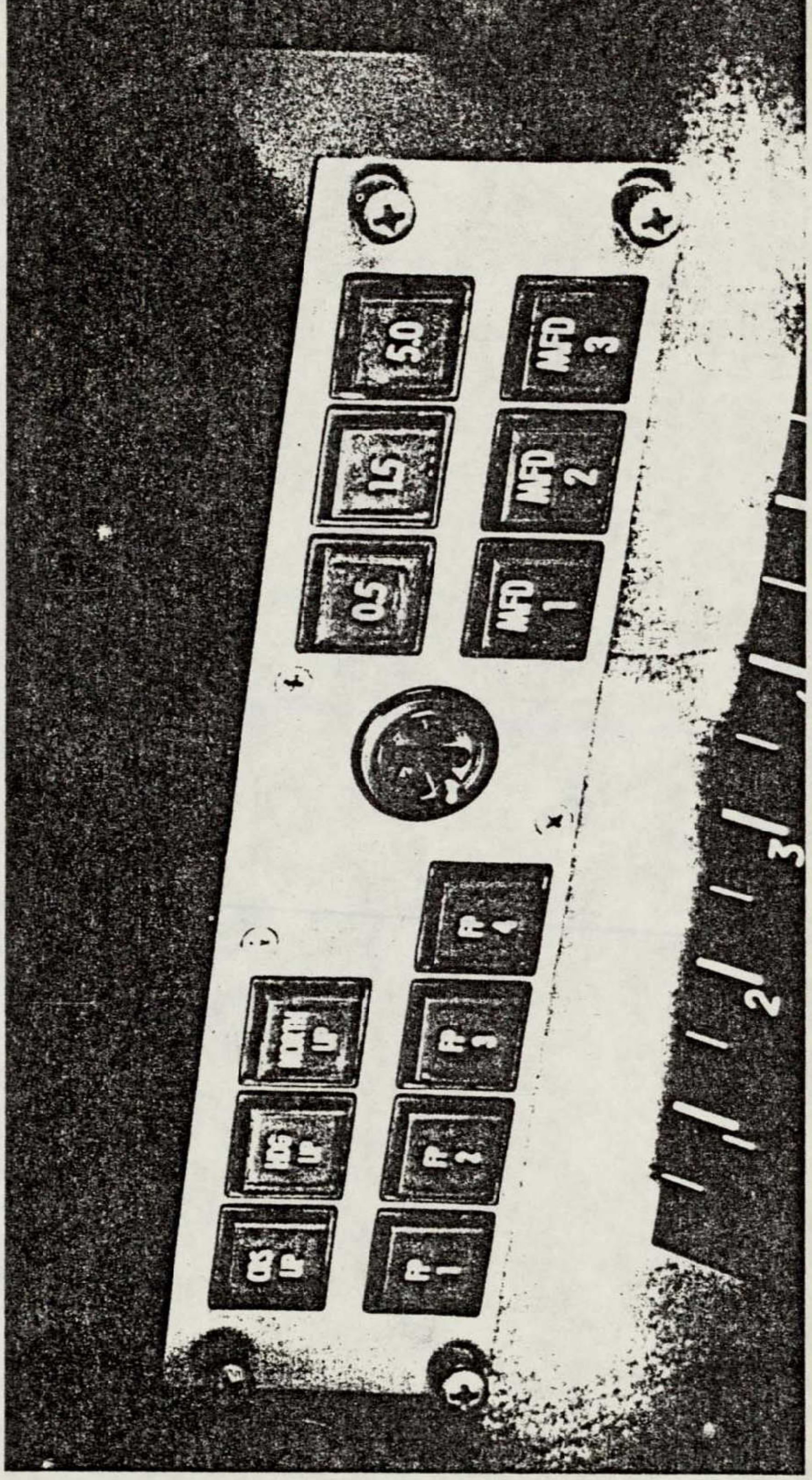
The mode initiation sequences suggested are based upon the relationship of the three control panels, the Mode Select Panel (Figure 6), the MFD Control Panel (Figure 7), and Alpha-Numeric Keyboard (Figure 8), and the three flight conditions, Fully Automatic, Flight Director Guidance, and the Raw Data Only.

The initiation sequence of each run of the simulator starts at the Keyboard. When the pilot is satisfied with the entries made there on he would depress the "Operate" button which should be relabeled "Initial Position". The simulated airplane then moves to and holds at a pre-determined position. The Mode Select Panel and the MFD Control Panel are activated and the lights in each mode button are illuminated. An amber light indicates the function is in standby and is available. A green light indicates the mode is selected and will function when one of the three flight modes is selected.



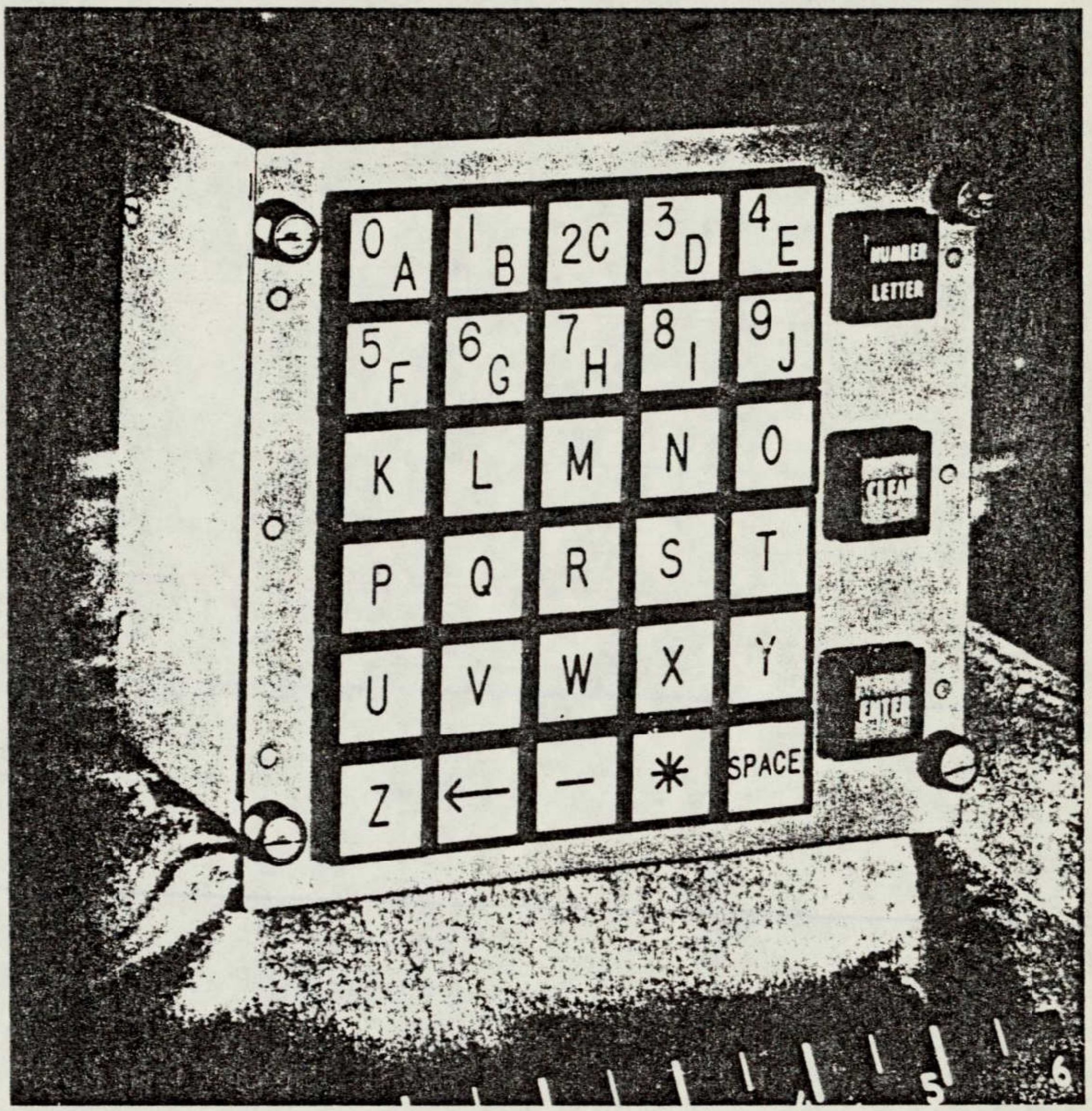
Mode Select Panel

Figure 6



MFD Control Panel

Figure 7



Alpha-Numeric Keyboard

Figure 8

The three flight condition modes are STBY on, (which should be re-labeled RAW DATA), FLT DIR, and FULL AUTO. These buttons will be illuminated amber when the "Initial Position" button is pressed. When one of the flight conditon buttons is pressed and illuminates green, the airplane would translate from the Initial Position to the first flight path waypoint with the system operating in an approach mode. This would produce a flight situation similar to an enroute flight segment and provide an operational atmosphere for flight to that first waypoint.

The flight conditon mode buttons would not be selected until the pilot was satisfied with all other mode selections.

The MFD control panel should have a memory circuit so that the last selections mode will remain illuminated green when the system is reset. The pilot would not have to re-enter a flight path or scale, etc. on a subsequent run, but would only change them as necessary.

The desirable STOLAND flight mode sequences are as follows:

A. Fully Automatic Flight.

1. System power on.
2. Alpha-Numeric Keyboard programmed.
3. Initial position selected
4. AUTO, SAS and A/T Servo switches engaged.
5. IAS, FPA, ALT or HDG mode selections made if desired.
6. Navigation system selected.
7. MFD control panel selected for Reference Flight Path, Scale and Orientation.
8. FULL AUTO mode select button depressed.

B. Flight Director Guidance Flight

1. System power on.
2. Alpha-Numeric Keyboard programmed.
3. Initial Position-selected.
4. SAS Servo switch engaged
5. IAS, FPA, ALT or HGD mode selections made if desired.
6. Navigation system selected.
7. MFD control panel selected for Reference Flight Path, Scale and orientation.
8. FLT DIR mode select button - depressed

C. Raw Data Only Flight

1. System power on.
2. Alpha-Numeric Keyboard programmed.
3. Initial Position - selected
4. Navigation system selected.
5. MFD control panel selected for Reference Flight Path, Scale and Orientation.
6. RAW DATA (formerly STBY ON) mode select button - depressed.

There should be no conflict between the pilot assist modes basic to the STOLAND system and the suggested mode initiation sequences if the Mode Select Panel functions and MFD Control Panel are programmed as follows:

A. The functions of the mode select panel are armed when the Initial Position button is depressed. The lighted buttons are illuminated amber indicating a standby condition that would be activated if selected.

1. The three servo switches on the panel should be spring loaded down in the "OFF" position and solonoid held in the "ON" position.

a.) AUTO This switch is the engage switch for the Auto-Pilot Servos for pitch, roll and yaw. In the "ON" position the airplane will be coupled to and follow the reference flight path selected or proceed from an initial position to a waypoint on the reference flight path, when released to fly by the "FULL AUTO" select button. If either the RAW DATA or FLT DIR buttons are depressed this switch will be de-energized and will turn off.

b.) SAS This switch is the engage switch for the Auto-Trim function of the "basic" stability augmentation system, and the engage switch for automatic operation of the Nozzles and Chokes of the "Backside" and "Frontside" stability augmentation systems. If any other stabilizing devise is incorporated into the system it would activate by this switch also.

c.) A/T This switch is the engage switch for the Auto-Throttle Servos. The "ON" position would hold the throttle setting determined by the preprogrammed flight path unless the mode buttons related to airspeed were pressed. Then this function would maintain the airspeed selected.

2. The Three Flight Condition Mode switches should illuminate amber indicating a standby status. When selected they would illuminate green and the simulated airplane would move from the Initial Position as follows:

a.) RAW DATA (formerly STBY ON)

The pilot would have raw data information for his position relative to the Reference Flight Path, or the IAS, FPA, ALT or HDG mode functions.

b.) FLT DIR The pilot would have the Flight Director commands available to follow the Reference Flight Path, or the IAS, FPA, ALT or HDG mode functions.

c.) FULL AUTO The simulated airplane will be coupled to the Reference Flight Path or other functions if the AUTO servo switch is on. If the AUTO servo switch is not engaged this mode would be the same as RAW DATA. The AUTO servo may be engaged after this selection and would function properly.

3. The four mode buttons IAS, FPA, ALT and HDG will arm when the Initial Position is selected. These modes may be selected either before or after a Flight Mode is selected.

a.) IAS SEL when selected will cause the autothrottle system on the throttle command to follow the airspeed set by the airspeed control knob. This speed can be changed if desired.

b.) IAS HOLD when selected will be the same as SEL except the airspeed cannot be changed. The IAS functions off will permit the system to follow any pre-programmed airspeed schedule.

c.) IAS SEL will allow the autothrottle system or throttle command set by the airspeed knob to track the airspeed preprogrammed.

d.) FPA SEL when selected would allow the Auto flight system or Flight Director system to fly or command flight path angles of variable values. The RAW DATA mode would display this variable angle.

e.) FPA HOLD when selected would cause the Autoflight system and the Flight Director system to maintain the selected vertical angle. The RAW DATA mode would display this angle.

f.) ALT SEL when selected would allow the Autoflight system or the Flight Director system to fly or command a transistion to the altitude selected.

g.) ALT HOLD when selected would cause the Autoflight system and the Flight Director system to stay on the altitude selected. This function would automatically come on as a transistion was completed using ALT SEL. These two functions would cause a depature from the Vertical path of a Reference Flight Path.

h.) HDG SEL when selected would allow the Autoflight system, of Flight Director system, to fly or command a transistion to the heading set by the control knob.

i.) HDG HOLD when selected would cause the Autoflight system to maintain the set heading. This function should activate automatically at the completion of a transistion by the HDG SEL function. Disengaging HOLD mode would shift the system to a wings level flight condtion prior to returning to the pre-programmed lateral path.

4. The four navigation mode buttons may be selected before or after the Flight Condition mode selections. Each switch when selected will take command and drop the other out.

a.) MLS, VOR/ILS, TAC when selected would provide a guidance signal from the Microwave Landing System, the Omni Range, the Instrument Landing System or the Tacan receiver. The CRS window would provide the necessary course information for these functions.

b.) REF F.P. select button would provide the guidance signal from the MFD Control Panel. This panel should be programmed with a memory circuit that would retain the last selected Flight Path, Display Scale and Orientation.

B. MFD Control Panel would be armed when the initial position is selected. The select buttons that were last used would be illuminated green indicating the Flight Path, Scale and Orientation of the Map Display. A memory circuit in this panel would retain the last selections.

CONCLUSIONS AND RECOMMENDATIONS

1. The current short haul operations in the United States and Canada are flown with a wide variety of airplanes. These operations are generally not STOL but rather CTOL airplanes flying short haul.

2. The small commuter airlines and local aircarriers operate very short routes using relatively light aircraft.

3. The majority of short haul air transportation is provided by regional and major aircarriers using the smaller jet transport aircraft like the DC-9 or B-737.

4. The flight simulation experiment indicates good flying characteristics are provided by the flight director. The backside stability augmentation system is satisfactory for operational use. This system should be tested in an operational experiment using STOLAND type system in a high density air traffic region.

5. The simulator set-up steps are cumbersome for repeated simulator approaches when evaluating operational procedures. The suggested mode select sequences would make a simulator experiment more efficient operationally.

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May 1978

APPENDIX 1

Electronic Attitude Director Indicator

NAS 2-9028

APPENDIX 1

This Electronic Attitude Director Indicator (EADI) is the instrument used during the simulator experiment. It was evaluated during the course of the study because of its importance and bearing on pilot work load. This appendix discusses some of the characteristics of the EADI.

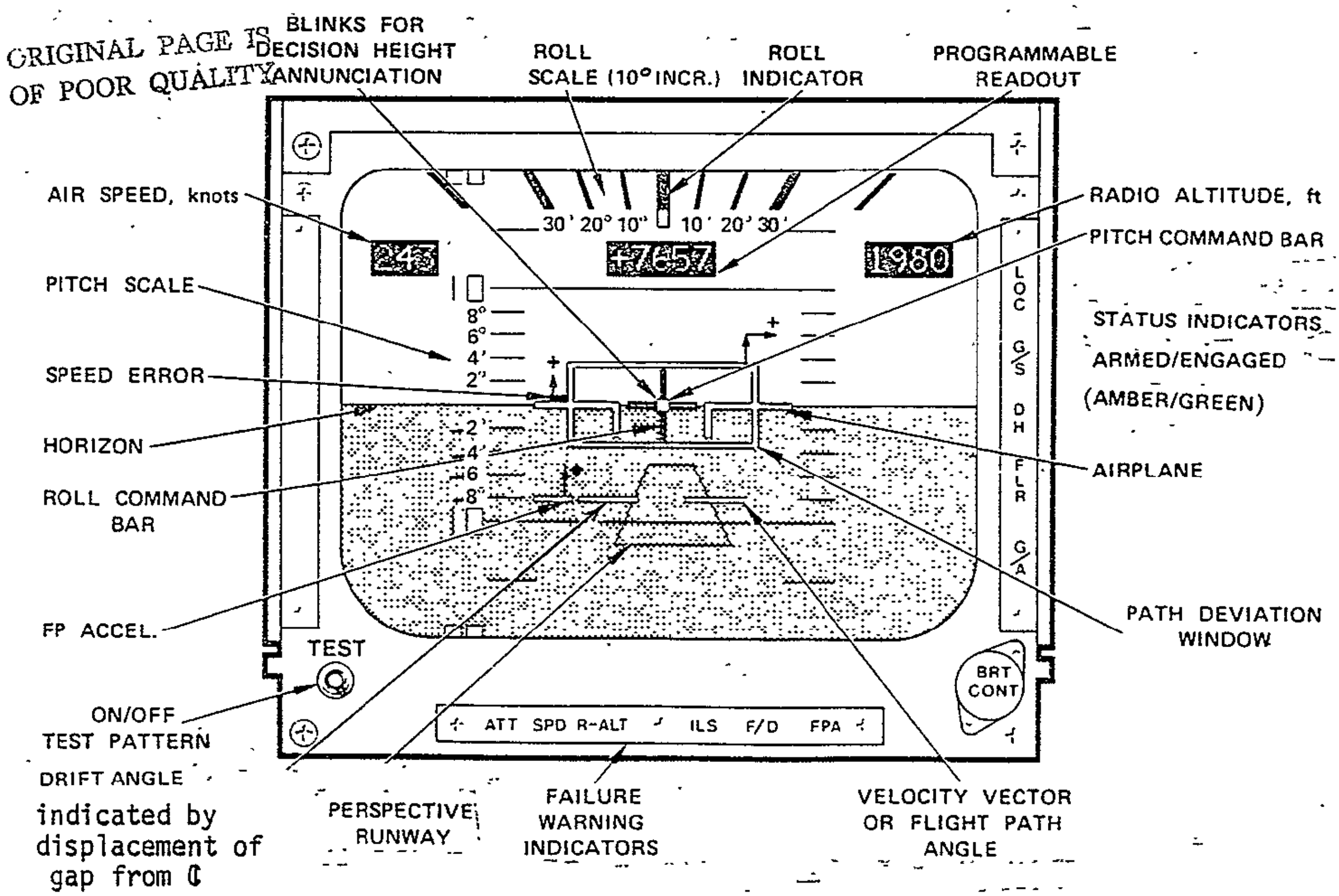


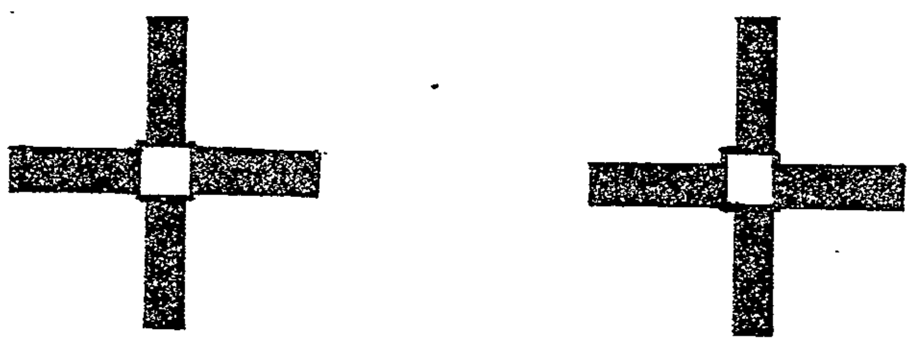
Figure A1-1
ELECTRONIC ATTITUDE DIRECTOR INDICATOR

The EADI functioned very well and provided the pilot commands for satisfactory following of the selected flight path during all modes of operation. The display clutter increased and the pilot work load increased correspondingly as additional information was added. Some of the information presentations on the display were weakened by their size and position.

These weaknesses became apparent during the simulator experiment. They did not prevent an operational evaluation of the approach system.

The weak characteristics of the EADI display are the pitch and roll command bar positions at zero and maximum, the throttle command bar, and the flight path deviation box.

The pitch and roll command bars center on a square. The width of the center square is greater than the width of the bars. (See Figure 3) The bars can be slightly off center producing a small command that will not get pilot response because the bars appear to be in a null position.

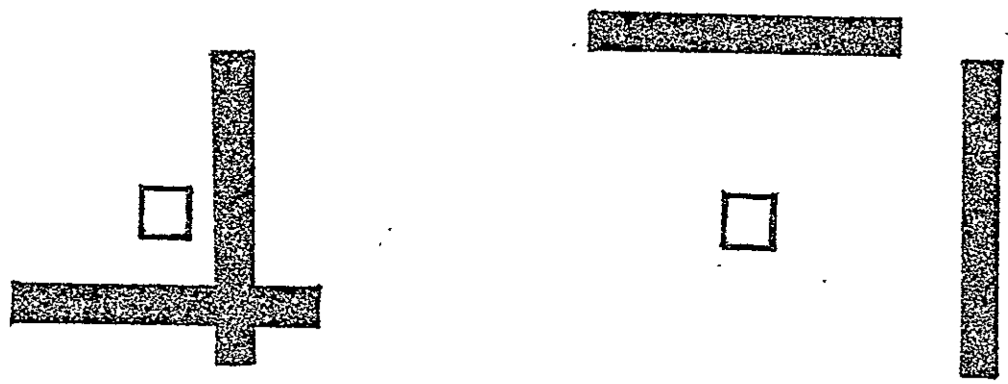


Exact nulled position   Apparent nulled position

Figure A1-2

The null position of the pitch and roll bars needs to be more obvious.

When the pitch and roll bars are at their maximum positions they become "Disconnected" from display and can be "Lost" in the EADI display. This can cause a delay in the pilots response as he goes looking for the command bars. (See Figure 4)



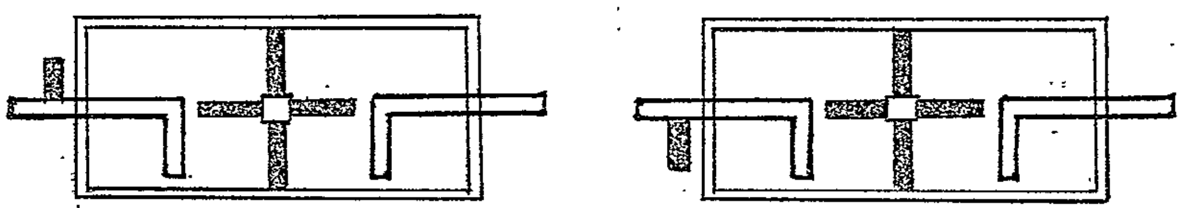
Small commands

Large commands

Figure A1-3

The command bars should be longer so that they could not "Disconnect" and should be thinner relative to the center square so that the zero command position would be more apparent.

The throttle command bar is displayed on the left wing of the EADI reference airplane. (See Figure 5)



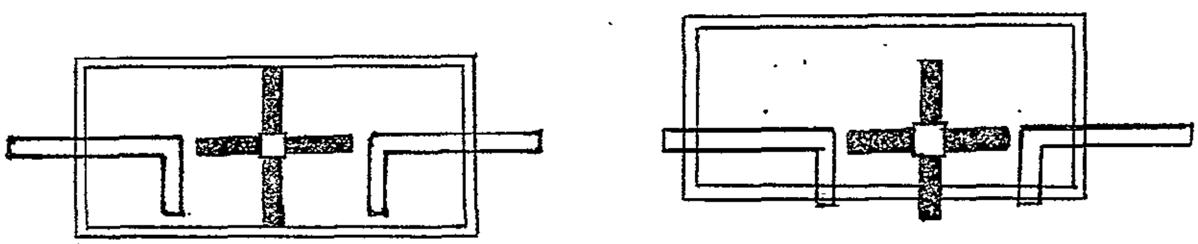
Advance Throttle

Reduce Throttle

Figure A1-4

The command to advance throttle is a black bar above the left wing. The reduce throttle command protrudes from the bottom. The zero command or null position is in the center of the wing. Small commands are covered by the wing and are not visible and therefore neglected which results in degraded vertical path performance.

The flight path deviation box moves around and on occasion will cover the throttle command bar. This can cause a delay in pilot response to throttle command and further decay in vertical path performance. The flight path deviation box can also produce an illusion of the pitch and roll bars showing a small command when they are actually nulled. When the airplane is centered on the reference flight path the deviation box is centered on the pitch and roll command bars. (Figure 6) If the flight path is not centered but the commands are nulled the off-center look of the display gives the impression of command bar displacement.



Nulled pitch and roll commands

Figure A1-5

Flight path deviation is supplemental reference information available to the pilot while following a Flight Director. Therefore it could be placed on the periphery of the EADI display without reducing its effectiveness. Moving the deviation box out of the center of the EADI display would reduce some of the clutter of the display.

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APPENDIX 2

INTERVIEWS WITH LOCAL SERVICE AIRLINES

NAS 2-9028

APPENDIX 2

INTERVIEWS WITH LOCAL SERVICE AIRLINES

The first portion of the second year effort was devoted to interviews with local service airlines. These interviews were reported in Letter Reports 4 and 5 of NAS 2-9028. This appendix is composed of portions of those reports.

Section 1. is a summary of the results of the operational interviews of the following airlines.

Airtransit

Catalina Airlines

Golden West Airlines

Rocky Mountain Airways

Sun Valley Key Airlines

STOLAIR

Swift Aire

Section 2. is composed of the operational interviews of the same airlines.

Section 3. is a summary of SHORT HAUL TRANSPORT as is currently flown using the Boeing 737 airplane. Typical routes of Piedmont, Frontier Airlines and United Airlines are reviewed.

SECTION 1

SUMMARY OF THE RESULTS OF OPERATIONAL INTERVIEWS

Table 1

Airline	Airplane in Service
STOLAIR	Britten-Norman Islander
Rocky Mountain Airways	DeHavilland Twin-Otter STOL
Golden West Airlines	DeHavilland Twin-Otter
Catalina Airlines	Grumman Goose
Sun Valley Key Airlines	Convair 440 DeHavilland Twin-Otter
Airtransit	DeHavilland Twin-Otter STOL
Swift Aire	NORD 262
United Airlines	Boeing 737

Some Short Haul Carriers and the Airplanes in Service

Table 1. tabulates the short haul airplanes in service by the airlines interviewed. The DeHavilland Twin-Otter is the only airplane currently in service that has a STOL configuration. Some of the small commuter type carriers operate light airplanes in the 3000 lb. to 4000 lbs. gross weight range with a STOL modification. This modification is unnecessary because the air carriers operate from runways long enough to accommodate the airplanes without the modification.

Rocky Mountain Airways uses the Twin-Otter STOL configuration on the occasion of a down wind landing. Airtransit uses the STOL configuration for all operations in their operation evaluation of a short haul STOL commuter route.

The short runway capability of the other airplanes listed is dependant upon their final approach airspeed. A low airspeed on final approach is usually associated with a short landing roll.

Table 2

Airplane	Number of Passengers	Cruise	Final Approach	Cruise Minus Final
Grumman Goose	9	110	55	55
Britten-Norman Islander	9	125	65	60
DeHavilland Twin-Otter	19	145	82	63
Twin-Otter STOL	19	145	66	79
Convair 440	28	180	115	75
NORD 262	29	215	115	100
Boeing 737	93	320	120	200

Indicated Air Speed Comparison Between Cruise and Final Approach

Table 2 shows that the difference between the final approach speed and the cruising speed of the smaller airplanes is about 60 knots. The final approach speed generally increases if the cruise speed increases. This is true for most airplanes with a simple wing flap for a high lift device.

The Twin-Otter improves the speed differential by lowering the approach speed with the STOL configuration. The larger airplanes improve the differential by increasing the cruise speed with power. Their corresponding final approach speeds are higher as a result. The higher performance airplane uses sophisticated high lift devices like leading edge slats and flaps, and trailing edge multi-segment Fowler flaps, to get the final approach speed down to 120 knots.

The airspeed differential between cruise and final approach has a pronounced effect upon the pilot technique used in the transistion from enroute cruise to landing.

The Grumman Goose is a seaplane with a very high drag profile. The pilot of this airplane can maintain cruise speed on a 3^{o} glide path and then slow to final approach speed by simply reducing power. The only difference between a sea landing and a hard surface landing is the landing gear extention. This airplane is being replaced by a helicopter which has a slightly larger passenger capacity, can land on a very small hard surface when rough seas prevent the seaplane from operating, and cruises slightly faster.

The Britten-Norman Islander also has a high drag profile that enables it to slow down while descending on a 3^{o} glide path. This airplane can stay at cruise speed while descending on a 3^{o} glideslope. Using this technique this airplane can mix with higher speed jet traffic without unacceptable interference. Another technique that is used with this airplane is to approach an airport on a track that will require a 90^{o} turn to final approach. While on this track the airplane descends on a 3 to 4^{o} glide path while slowing from cruise final approach speed. The descending final turn is made close in to the runway and a landing is made close to a runway turnoff point. This permits operation at a busy terminal with a minimum of interference with the faster traffic.

The Twin-Otter is also able to slow from cruise to approach speed on a 3^{o} glide slope and is fast enough to fit in with jet traffic. The airplane can also fly a 6^{o} glide path. The technique used when planning this steep approach is to decelerate about 2 miles from the glide path intercept and extend approach flaps. When established on the glide path the landing flaps are extended and the airspeed reduced to final approach speed.

Another technique used during visual flight with this airplane is similar to the Britten-Norman Islander 90^{o} turn in. The pilot maintains cruise speed right up to the terminal area, either level or in a descent. The airplane slows to final approach speed in the terminal area and the landing flaps are extended. Then a descending turn on a $4\text{-}5^{o}$ descent path to the runway is made.

The Convair 440 has a difficult time flying a steep path during an approach and is usually decelerated in level flight prior to an approach. Its thrust reversal system and brakes enable it to land on short runways.

The NORD 262 is able to fly at much higher cruise speeds because of its higher thrust to weight ratio. High drag can be obtained from the propellers in flight idle or ground idle. Therefore this airplane is able to stay up with the higher speed jet traffic and then slow down at the last minute to approach speed. Short field performance is obtained by the use of ground idle and anti-skid brakes.

The B-737 is a conventional turbojet airplane that must be slowed down prior to intercepting a 3^{o} glideslope in order to make a power stabilized approach. If the airplane is at 200 kts IAS and descending on a 3^{o} glide path, 5 miles are required for it to slow to approach speed, with the throttles at idle and the flaps extended as the maximum limit airspeeds are reached. The technique most often employed with this airplane is to slow in level flight to 200 kts IAS, extend 5^{o} of flaps and use speed brakes to aid airspeed control during descent. The airplane has anti-skid brakes and a thrust reversal system which helps in reducing runway length requirements. Even so, about 6000 feet is the minimum runway length the airplane can be safely operated on.

Table 3

Airline	Avionics	Flight Director	Autopilot
STOLAIR	2 VHF 1 ADF	no	no
Rocky Mt.	2 VHF 2 ADF 1 MLS	yes (not MLS)	no
Catalina	2 VHF 1 ADF	no	no
Sun Valley Key	2 VHF 1 ADF 1 RNAV (1 waypoint)	no	yes
Airtransit	2 VHF 2 MLS 1 RNAV (30 waypoints)	yes (not RNAV)	yes (not IFR)
Swift Aire	2 VHF 2 ADF	yes	yes
United	2 VHF 1 ADF	yes	yes

Navigation Equipment in Use

Table 3., tabulates the navigation equipment used by the short haul operators. All of the airplanes are equipped with dual VHF navigation radios. The ADF is standard with all except Airtransit. The MLS systems are limited to Rocky Mountain for their unique mountain operation and Airtransit for their Short Haul Commuter experiment.

The pilot procedures and techniques for speed and configuration management of short haul carriers during instrument weather conditions are determined by ATC and the airspeed capability of the airplanes. The faster airplanes fit in with the normal flow of traffic. The slower airplanes maintain cruise speed up as long as practical. All of the airlines fly a VOR to ILS transistion. The arriving airplane is either vectored or is following a VOR radial that intercepts the final approach course of the ILS. The faster airplanes are slowing from cruise speed to approach speed. The slower airplanes are holding cruise speed. The ILS is selected on the navigation radio and the intercept followed by basic data, Flight Director or Autopilot. The point of localizer capture is usually several miles from the glide slope intercept. The turn onto the Localizer is usually less than 45° so the use of 30° bank angles and the corresponding turn rates do not present any operational problems. If a Radar Vector results in an intercept point within 2 miles of the normal point of descent then the intercept angle is restricted to 15-20°.

When the airplane reaches the point of descent, the Glide Slope capture, ATC removes the airspeed restrictions and the configuration can be changed from cruise to approach to landing.

Rocky Mountain Airways uses a VOR to MLS transistion. Airtransit uses an RNAV to MLS transistion. The MLS glide slope in each case is 6°. The Twin-Otter pilots must slow the airplane to 125 kts or less prior to intercepting the 6° path or create a problem with airspeed management on the approach. The VOR and RNAV navigation systems are used to position the airplane for an intercept and transistion to the MLS. The MLS has a seperate receiver but uses the same navigation indicator as the VOR or RNAV. The pilot must select MLS and tune the frequency. The VOR-MLS approach is a raw data approach in a mountainous region and has a greater cockpit workload than the Airtransit Flight Director MLS approach in a metropolitian area.

The 6° MLS approach does have some limitations. The Rocky Mountain Airways approach into Aspen Colorado is to a one-way runway. On occasion there will be a significant tail wind during the approach even when the runway winds are OK for landing. In this case the airplane will have a high rate of descent during the initial descent on the glide slope and then a rapid airspeed increase in the wind change near the ground. The pilots will usually fly the approach at minimum speed to reduce the rate of descent and anticipate the airspeed increase during the wind shear.

If a decrease in airspeed is experienced during the wind shear the Twin-Otter's thrust response is adequate to provide good acceleration. The airplane flight path control is very good and the tracking task required to follow the localizer and glide slope can be accomplished with normal pilot effort.

The Airtransit approach to Runway 24 at Victoria Park had a turn greater than 90° on to a final approach segment just 2 miles from the MLS Glide Slope intercept. This approach profile was producing problems with alignment with the final approach course and the pilots workload in selecting the MLS approach. The profile was changed to a 60° turn, 3 miles from Glide Slope intercept and that solved the alignment and approach management problem. All of the airplanes used in short haul are able to operate in turbulance and with cross winds during landing. The general technique is to add half of the steady headwind component to the approach speed, and if the winds are gusty then the gust factor is also added up to a specific limit. The B-737 never adds more than 20 kts to the approach speed as a wind correction. The cross wind is compensated for during landing by holding a wing down into the wind and opposite rudder to make a slip. The lateral response of the control systems do not present any unusual problems with crosswinds or turbulance. The crosswind limits of the airplanes are conservative enough to have wide safety margins.

The cockpit workload does not increase beyond the level required for IFR flight in a busy terminal area. The use of a two-pilot crew is necessary to keep the workload satisfactory. The Airtransit workload is significantly reduced by having the RNAV system guide the airplane right to the point of intercept of the MLS approach. When the ceiling and visibility during the Airtransit commutor operation is above 600-1 the pilots may use the RNAV 6° path to the runways. This reduces the cockpit workload as there is no requirement to switch or change the guidance system.

There is no apparent change in criteria for balked landings. The pilot assesses his position when in visual contact with the runway and makes the determination of a safe landing. In all cases the go-around procedure is to add maximum power, rotate to a climb attitude, reduce the flap setting to approach flaps and accelerate to 10-15 knots above 1.3 V_s for initial climb out. The deviation criteria for a category 1 ILS is that the airplane must be within one dot of both localizer and glide slope at minimums. The airspeed is also required to be stabilized at not more than 10 knots above the target airspeed. There is no history of balked landings in any of the operations reviewed. The few occurances noted were caused by traffic conflicts and not the flight path control or approach management.

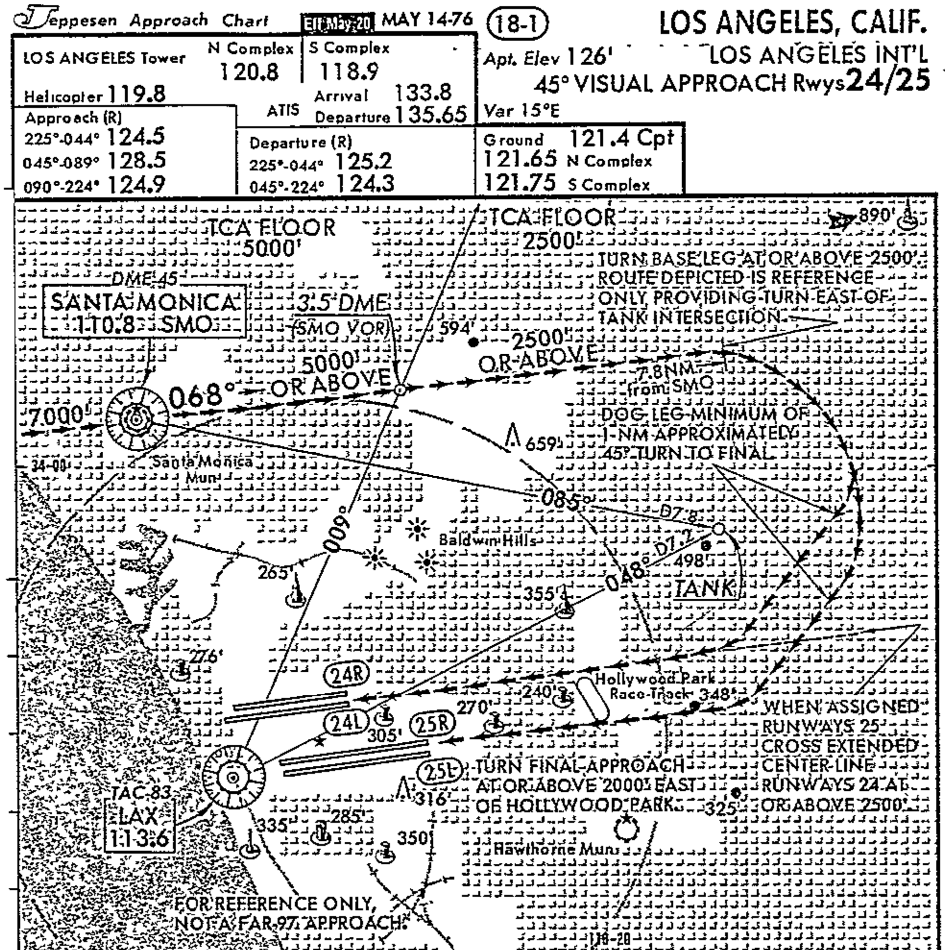
None of the Air Carriers attempt to fly a curved path approach under actual instrument flight. During visual weather flight conditions a variety of curved paths are flown. None of these are a FAR-97 approaches. These curved approaches can be done only during VFR conditions and when VFR approaches are in progress. The 45° Visual Approach Rwys 24/25 at Los Angeles International is flown by three of the airlines interviewed. (See Figure 1).

The airplanes used are the Twin-Otter, NORD 262 and B-737. The descent path is usually 3-4° with a turn radius of 10,000 to 15,000 feet if the 45° intercept is established, then a 30° bank is usually required to make the 45° turn to final.

The technique for flying this visual curved path is to establish a constant descent path and final airplane configuration prior to reaching the 45° turn to final approach.

The Twin-Otter and NORD 262 have no difficulty in flying this visual curved path approach. The B-737 must be slowed to 180 kts or less

Figure A2-1



45° VISUAL APPROACH

When VFR conditions exist and visual approaches to Runway 25 Right and Runways 24 are in progress, clearances to aircraft inbound from the north and northwest will be given utilizing the following phraseology:

"(IDENT) CLEARED FOR A 45° VISUAL APPROACH TO RUNWAY_____."

A descent profile of approximately 3° starting at 7000 feet over SMO VOR may be made with reference to the minimum altitudes above.

prior to the turn to final or the approach cannot be stabilized by 500 feet above touchdown.

System Related Items

The operational control of the short haul routes examined adapt well to the ATC requirements of heavy traffic areas like San Francisco and Los Angeles with radar control and altitude reporting. If a flight deviates 200 feet in altitude or 1 mile in track in these areas, that flight is interrogated by ATC as to why the deviation. This is the ATC tolerance of flight path errors.

The only airline using a preprogrammed RNAV profile is Airtransit. These profiles were usable under most of the flight conditions and were very successful. Sun Valley Key Airlines uses a simple RNAV system to help define a direct route to an airways intersection and a controlled path from that point to the airport.

The use of RNAV seems to be an economic decision. If the pilots can do the job without the equipment, and if ATC has radar and is willing to provide the vectoring necessary to accomplish the job then the airline has no requirement to finance RNAV equipment or provide the training necessary for its use.

The preprogrammed RNAV profiles used by Airtransit were excellent. The routes were modified during the experiment to make the entry to each STOL port better. It was necessary to change the profile enroute when wind conditions dictated a change in runway. The RNAV profiles were acceptable in all of the weather conditions encountered. The autopilot was not used during IFR flight because of the certification requirements. The flights were short enough that this never became a factor in the cockpit workload.

The enroute modification of the RNAV profiles were easy to accomplish by using the "offset leg" function or skipping a waypoint and proceeding direct to the next waypoint.

The RNAV system provided for a very high degree of consistancy in flight path. As the experiment progressed the traffic controllers operated more as a radar following than as a control.

APPENDIX 2

SECTION 2

OPERATIONAL INTERVIEWS

Airtransit

Catalina Airlines

Golden West Airlines

Rocky Mountain Airways

Sun Valley Key Airlines

Swift Aire

STOLAIR

Operational Interview - Airtransit, Ottawa, Canada

February 14, 1977

Interview with Mr. Frank Black, Program Director and a flight with Mr. Peter Caws, Project Pilot, Air Transport Ministry, LIOA Ministry of Transport, Tower C, Ottawa, Ontario, Canada. Frank Black was chief of the Division that conducted the Airtransit Operations, Peter Caws was one of the Airtransit Captains.

Airtransit Company was organized as a subsidiary of Air Canada. The pilots were hired solely for the project. They were hired as captains or first officers depending upon their total airplane experience. The background of most of the pilots was military. Several of the pilots were retained with the Ministry of Air Transport at the conclusion of the project.

The experiment was a 26 million dollar exercise involving two STOL ports (Rockcliffe, Ottawa, and Victoria Park, Montreal), 6 airplanes and 48 pilots. There were 4 basic routes with 8 approaches. (*1) 4 - RNAV/MLS and 4 RNAV/RNAV. Both runways are 2000' long and 100' wide.

A 4 hour briefing on Feb. 14, covered information on system engineering and equipment installation, system operation, operational procedures, and STC procedures and policies.

A 2.5 hour flight on Feb. 15, in a Twin-Otter airplane covered two Airtransit RNAV routes and 4 approaches, 2 RNAV/RNAV and 2 RNAV/MLS.

The navigation system consists of a single unit Collins RNAV, with 30 programmable waypoints, dual MLS receivers, dual FD-108 Flight Director, and dual HSI course indicators. The RNAV unit operated primarily DME/DME with secondary VOR/DME and if that dropped out it would operate in memory for 2 minutes. It has auto-turn capability but would only auto-tune stations programmed for each particular waypoint. Each radio NAV-AID was programmed by number and could be selected by entering that number into the waypoint. If a station was off the air, the auto-tune would not select an alternate station. The route with its corresponding RNAV approach had to be entered into a 'card' reader for each trip. The MLS receiver was separate and had to be selected and tuned manually to fly the MLS portion of the approacn. The HSI course information was not servo driven but required the pilot to select the course between waypoints in order to have the course needle position. A second needle would always point to the 'to' waypoint. If the course needle were to be aligned with the RNAV path then the autopilot NAV function would follow that course. The glideslope function of the autopilot would follow the vertical RNAV path but would not follow the MLS glideslope. The autopilot function was not certified for IFR. Most of the approaches were flown using the Flight Director. The Captain and the First Officer alternated making approaches.

*1 - RNAV/RNAV is the area navigation route terminating in a RNAV approach
RNAV/MLS is the area navigation route terminating in a MLS approach.

The commuter service was operated from 7 am to 10 pm daily, with 5 airplanes in service and the 6th in maintenance. Several times when they were operating on a 30 minute departure schedule 4 of the airplanes would be in the air at the same time. The normal block time was 45 minutes. The experiment included bus service from downtown Ottawa and from downtown Montreal, to their respective STOL ports. The ground time at Ottawa ran about 45 minutes, and the time at Montreal about 30 minutes. Even with the longer block time (Air Canada provides the same service using DC-9's requiring only 25 minutes block time) the total travel time, between city centers was 1 hour and 30 minutes shorter than using Air Canada. The cost to a passenger at the beginning of the experiment was 50% of the regular Air Canada commuter fare. Later the price was raised to 75% without any significant change in loads. And finally to 110%. The drop in load factor was still very small.

The 300 series Twin-Otter airplanes carried only 12 passenger seats. The passenger comfort level was equal to the other commuter service.

The RNAV flight procedure set up was initiated after the passengers were boarded, the engines started, and all airplane and navigation systems on and operating. The pilot would obtain his departure and arrival clearance and select the corresponding route program card. Example: Route "East 24" (Figure 1) is east bound from Rockcliffe Runway 27. Arriving on Victoria Park Runway 24. This route is 107.5 n.m. in length and has 20 waypoints. Waypoint 1 is the runway at the start of the take-off roll. Waypoint 2 is the departure end. 3 and 4 usually form the departure cross wind leg. 5 or 6 are the initial on course waypoints. The other end of the route has wpt 20 (the missed approach waypoint) at the far end of the runway. Wpt 19 would then be the threshold of the runway - wpt 18 the final approach waypoint and wpt 17 the initial approach waypoint. (Figure 2)

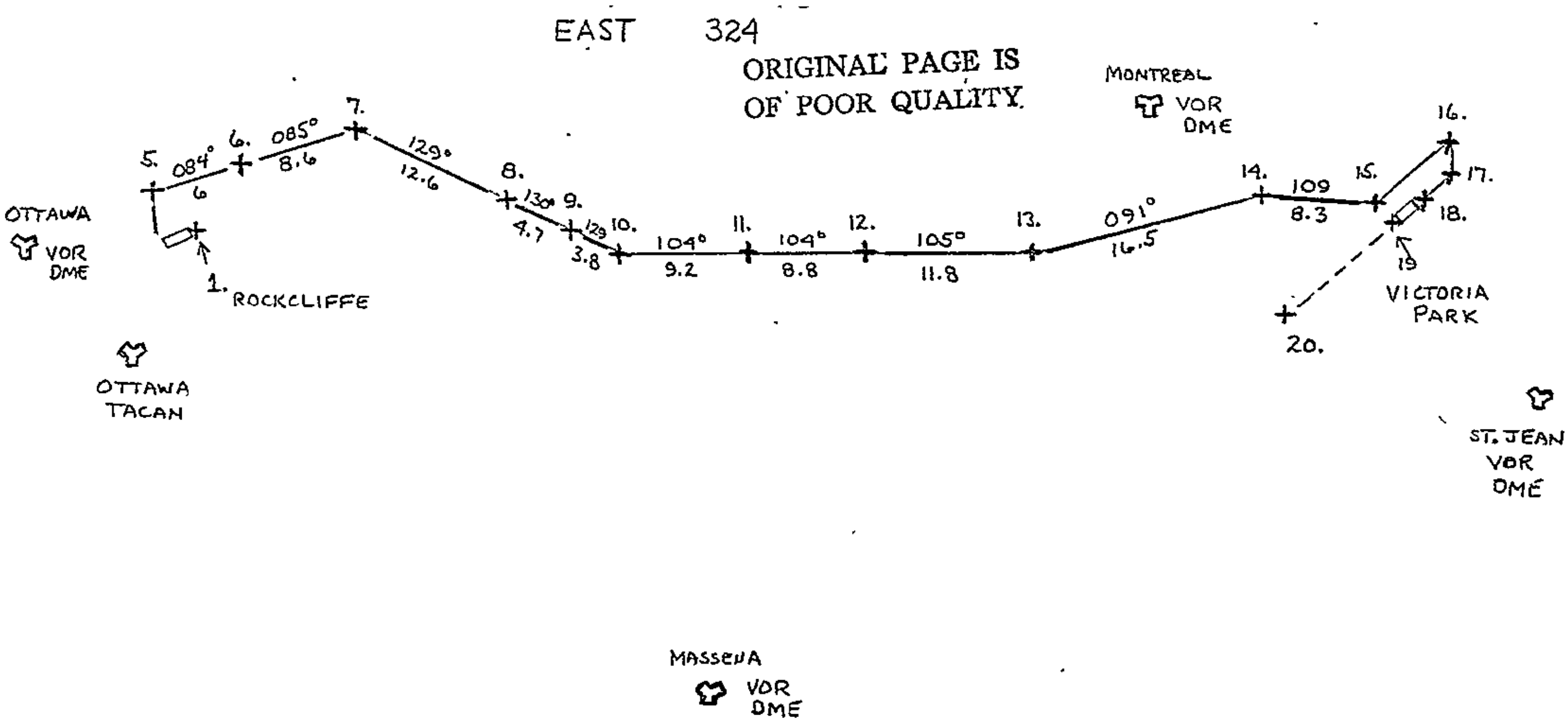


Figure A2-2
RNAV Route EAST 324 Between Rockliffe, Ottawa and Victoria Park

The pilot would verify that the correct route was programmed by holding a sequence button that would step each waypoint through, indicating the heading and distance on the CDU. Each course heading and distance to each waypoint was checked as each waypoint number appeared. On most flights the pilots would skip the first few departure waypoints and start the RNAV portion of the route at waypoint 5 or 6. The accuracy of the system with DME/DME valid was 0.4 n.m.. At low altitude these first few waypoints would have larger errors, and with these waypoints close together the pilots preferred to select the Flight Director to the go-around mode, set the 'to' waypoint to 5 or 6, and then visually navigate by distance and heading to that waypoint. Approaching the first enroute waypoint the pilot would have heading and altitude Flight Director commands for that point. 0.6 n.m. from the waypoint the system would shift to the next waypoint and the deviation indications would be for the next leg. If the next waypoint altitude was higher than the passed waypoint, the deviation would show the vertical path to be below the airplane. The vertical path is calculated from waypoint to waypoint and when the system switches prior to reaching a waypoint the slope of this path when extended back to the airplanes position would put the path below the airplane. The pilot technique was to ignor the Flight Director commands until the vertical path deviation centered. The same thing happens in the lateral plane when there ia a course change. The pilot technique again was to ignore the Flight Director until the path centered or the Flight Director commands provided a turn in the direction of the heading change.

The system has a course offset capability. It could offset along flight path, which is used to adjust the position of altitude changes or it could offset cross track. The cross track offset moves the entire programmed route flight left or right and must be taken out in order to put any waypoint back on the original path.

The RNAV airways were 4 N.M. wide and formed a racetrack pattern going East on the North side and West on the South side. The routes were flexable and ATC sometimes changed routes to accommodate "pop-up" conflicting traffic or to allow for landing direction changes. The pilots were permitted to shorten the preplanned route when possible and did so by selecting another waypoint and going direct to it. There was only one major traffic conflict which resulted in a jet airliner and a Twin-Otter trying to occupy the same airspace. There were several occasions where Montreal/Dorval jet traffic for RW 24 was vectored East and North of Victoria Park. This was a very small distance deviation for the jet traffic and no pilot, or airline complained about the deviations.

The Twin-Otters were operated at maximum cruise, about 145 kts IAS during level flight. Climb airspeed was about 145 kts and the descent airspeed was about 155 kts. If the route terminated with a straight in MLS approach the pilots would maintain 145 kts and 2000' altitude until 6 miles from the runway. At this point they would slow to 90 kts, put 10^{0} flaps down, and select MLS. The system would indicate MLS localizer and glideslope deviations. The Flight Director would capture the MLS signals, usually with small errors as the RNAV path and the localizer were coincidental. The Flight Director glideslope capture was a 6^{0} nose down pitch command that would wash out in about 15 seconds. After glideslope capture tne power would be retarded and airspeed reduced to 80 kts, and the prop control set to take-off RPM. The indicated airspeed for the balance of the final approach would be 70 kts. The stopping technique was to use flat pitch reverse and apply brakes. The average ground roll was about 300 feet.

If the approach required a downwind and base leg, the airspeed would be 120 kts on downwind while descending to 2000 feet. The pilots would slow to 90 kts on base, extend 10° flaps and turn to an intercept heading for the MLS localizer. The procedure from this point would be similar to a radar vector for an intercept of the MLS.

If the approach was going to be RNAV/RNAV, the vertical profile called for the airplane to arrive at the intitial approach waypoint at 2000', start a descent to about 1300 feet above field level at the final approach waypoint, 2 n.m. from the runway threshold, and then descend on a 6° angle to the runway. The 6° approach from here is the same path as the MLS.

The approach minimums were 300-1/2 for MLS. RNAV minimums were 500-1 at Rockcliffe and 600-1 at Victoria Park.

Route "East 24" with the approach into RW 24 Victoria Park was modified between January and June of 1975.

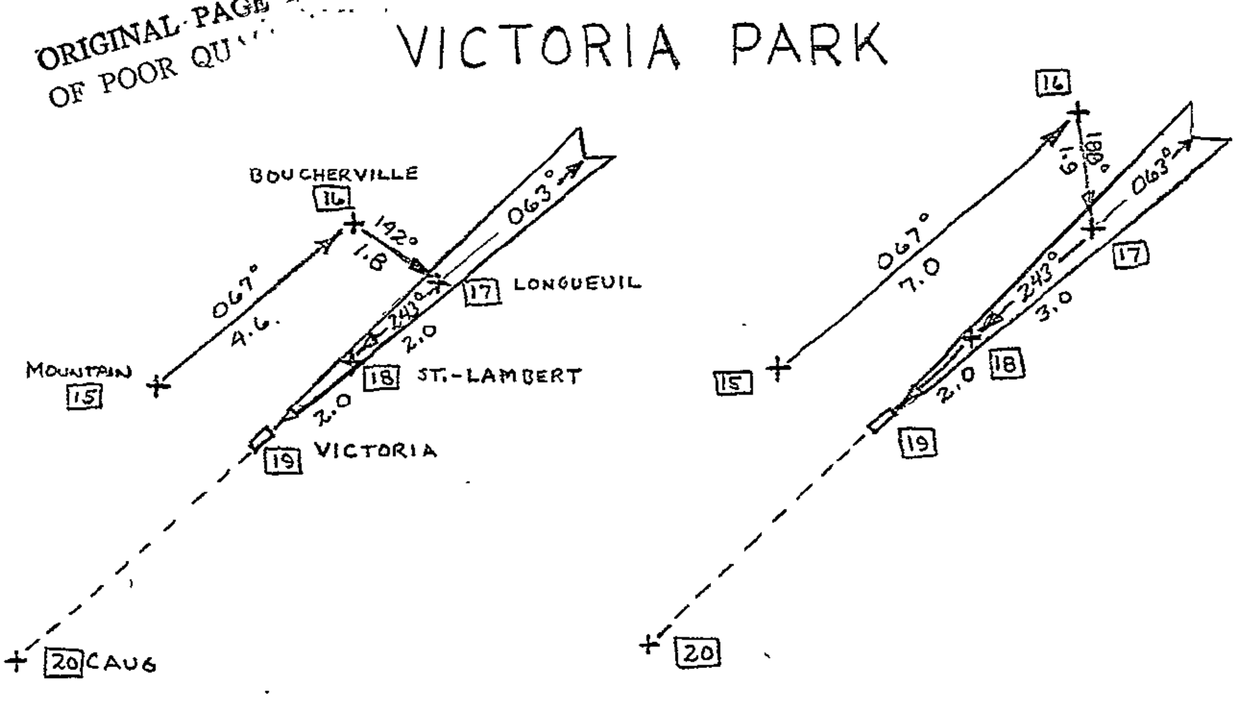


Figure A2-3
RNAV Terminal Area Route at Victoria Park, Montreal

The original approach arrived at waypoint 15 at 3000', waypoint 16 was 067° and 4.6 n.m., with a course of 142 degrees. Base leg was 142° and 1.8 n.m.. The final approach course being 243° then required a turn of 101°. This turn was difficult to make when the switch to MLS was necessary. With strong West winds the pilots had to use a 40° bank angle to make this turn. The FD-108 Collins Flight Director used in the 6 line airplanes would not command bank in excess of 30°. The pilots would know with experience that more bank was required in order to get into position and they would ignore the Flight Director and use sufficient bank to keep from overshooting their desired path.

The short distance to the 6° glideslope also contributed some difficulty. The solution was to extend the downwind leg segment 2.4 miles to a total of 7 n.m., and move the initial approach waypoint out one more mile to three. Thus there was a 127 degree turn onto the base leg, which has a course of 188° and a turn of only 55° onto final. The base leg now provided a near normal intercept heading for the MLS approach. (See Figure 2)

The MLS installations at each STOL port were temporary. The ground equipment was installed to the right of the runway opposite the touchdown point. The localizer centerline was set on a 2° angle to the runway centerline. The RNAV path was programmed coincident with the MLS localizer. The airplane flying on the RNAV path would approach the runway with a slight angle from left to right. At minimums, zero wind, the airplane would be just to the left of the left edge of the runway but headed slightly to the right. Alignment with the runway centerline with this slight offset was no real problem to the pilots. Most days the approaches were flown with a crosswind and the airplane alignment with the runway was still an easy operation.

All of the approaches had a wings level portion of final approach of at least 4 miles. There was no attempt to turn final any closer than this, and there were no curved approaches flown.

The pilots did not have previous airline experience so the training and the operational experience they acquired during this project appeared to them to be "normal" airline operations. They operated the RNAV system very well by doing most of the "card" programming on the ground. Occasionally an airborn change was made, if the landing direction was changed during flight. Then a different card was inserted prior to reaching the destination. No attempt was made to reprogram in the terminal area.

Operational Interview - Catalina Airlines of Long Beach

Long Beach, California February 3, 1977

Interview with Randall A. Bombard, General Manager.

Chief Pilot of the Airline is Joe Emmett. He performs all the training and checking for the airline. The FAA does not keep an examiner seaplane qualified.

Catalina Airlines has a unique operation between Long Beach and Avalon, Santa Catalina Island, and Los Angeles Harbor and Avalon. Their longest flight leg is 15 minutes block time.

The Airplane they use is the Grumman G21A Goose, a one pilot and nine passenger seaplane. They have a fleet of 7. Their latest built airplane has a manufactures date of 1945.

During normal operations the airplane lands in the open sea on the lee-side of Catalina Island and taxies up onto the ramp at the Avalon terminal. Operations at Los Angeles Harbor are similar. At Long Beach the airplane lands on the hard surface runway. The seaplane imposes severe limitations on flight operations. It cannot operate off the Catalina hard surface runway, which is a 45 minute drive from town, it can't land in the ocean if the water is too choppy, and it is restricted to daylight only operations.

The only instrument approach flown is the ILS at Long Beach. That approach usually has a straight in entry.

The approach into Avalon is unusual. The landing gear is such that even a partially extended wheel would be damaged by a water landing. So the pilot makes 4 checks on the landing gear prior to landing to see that it is fully retracted. He makes a mechanical linkage check. The handle and cables, a hydraulic check, a visual look from the cockpit and a visual check by a company employee on the ground as the seaplane flies by. The seaplane must land parallel to the major swells and should not have either of the wing pontoons touch the water until the airplane has slowed down.

These limitations restrict flight operations excessively so Catalina Airlines purchased two helicopters for service to the Island. The helicopters have 9 passenger seats and will operate with one pilot. Catalina is constructing a heliport very close to Avalon. The helicopters will be able to operate at night and when the water conditions prevent the seaplane from landing. One of the helicopters has been certified and is presently in service.

All seaplane flights are conducted day VFR, and as direct as possible after take-off. The pilot turns to a heading direct to Santa Catalina and tunes in that VOR immediately. There is a company owned NDB at the company terminal ramp at Avalon. The flight proceeds inbound, on the VOR radial to a predetermined bearing then turns into the landing area. A landing gear "up-check" is made. The airplane is turned on a downwind leg depending upon the sea condition, turns base and makes a low turn to final and a very shallow final approach. The airspeed is maintained at 110 kts to the NDB-VOR intersection then reduced to 65 kts with half flaps extended. This is maintained until on final approach, where they slow to 55 kts and extend full flaps. The water landing requires about 700'. A runway landing about 1000'. Water take-off distance depends upon the surface conditions and can take up to 2000'.

During the summer season most trips are full. Catalina Airlines fly 14 round trips to Avalon per day (water permitting) during the summer, and 7 round trips during the winter.

The steepest glideslope used is the 3 degree ILS at Long Beach, this is used only when the visibility there is restricted.

The airline does not use any terminal area transistions. The only approach plate is the Long Beach ILS. The airplane seldom gets above 1000' MSL or exceeds a 20 degree bank turn. The ILS when used is a raw data approach with an intercept at about 1000 feet. The airplane is speed stable and requires about 40% of power to maintain 65 kts with the gears and flaps down. The tracking of the localizer and glideslope are very good. The control forces are only moderate and the airplane is very stable.

Usually strong winds close down the operations because of the effect on the water. The cross wind limit on a runway is 18 kts. A water landing is made parallel to the major swell without regards to drift. The water landing is always a cross wind or head wind, never a tail wind. Thirty to 50 kts cross wind doesn't cause a particular difficulty in a water landing.

When landing in the water the pilot allows the airplane to weather vane into the wind as it stops. During a particularly high cross wind water take-off a pilot turned into the wind and one of the pontoons hit a swell and broke from the wing. Its guy wires held it to the airplane during the flight back to Long Beach.

The cockpit workload required in this operation is considerably more that conventional land airplanes. The cockpit equipment is simple. They have two Nav/Com VHF radios, one mounted on the lower instrument panel and the second overhead slightly behind and to the right of the pilot. This radio is usually left tuned to Santa Catalina VOR and the company frequency as it is difficult to see. The ADF is on the lower instrument panel and is tuned by the pilot leaning forward and reaching to the right. The cabin is poorly insulated and the cockpit noise is excessive with the engines running.

They have 12 pilots. Most of them were hired on the basis of their seaplane time. The most junior pilot has been with them 5 years.

The Airline doesn't like to hire new pilots for the seaplanes because of the time required to make them proficient and competent in this operation. The helicopter pilots will be a separate pilot group and will not be cross qualified.

This seaplane is performance limited. The pilots claim it doesn't have single engine performance at maximum gross weight. When operating close to maximum they keep the airplane low until cruise speed is obtained. The airplane is capable of landing in open sea so turns are not attempted other than to parallel the greater swell ot the sea. If a surface craft should appear in the way during a water landing approach, the visual procedure is to carry power long enough to allow a landing beyond the obsticle. This has occurred several times during low (500-1) visibility conditions at Avalon. The boats just were not visible on the water until the seaplane was about to land.

This airline operation is not controlled by ATC. The airplanes are not equipped with transponders. Sometimes when inbound to Long Beach pilots will contact approach control for sequencing and traffic prior to tower contact. The rest of the communications is to the tower or to company control.

The use of RNAV would not change their routes. All flight legs are straight lines and short distances.

The special VFR (500-1) for which they have certification to operate allows them fly nearly every day, year round. The sea conditions at Santa Catalina limits the operation much more than ceiling and visibility.

The problem of runway clutter is different from other conventional operators. Los Angeles Harbor is littered with floating debris and occasionally floating material is in the ocean near Avalon. This poses a real problem. Striking some floating material could and has caused leaks in the seaplanes hull. Fortunately, in all instances so far the airplane has been able to taxi onto the terminal ramp before taking on any amounts of water that would cause a floatation problem.

The floating debris has become more of a problem the last few years.

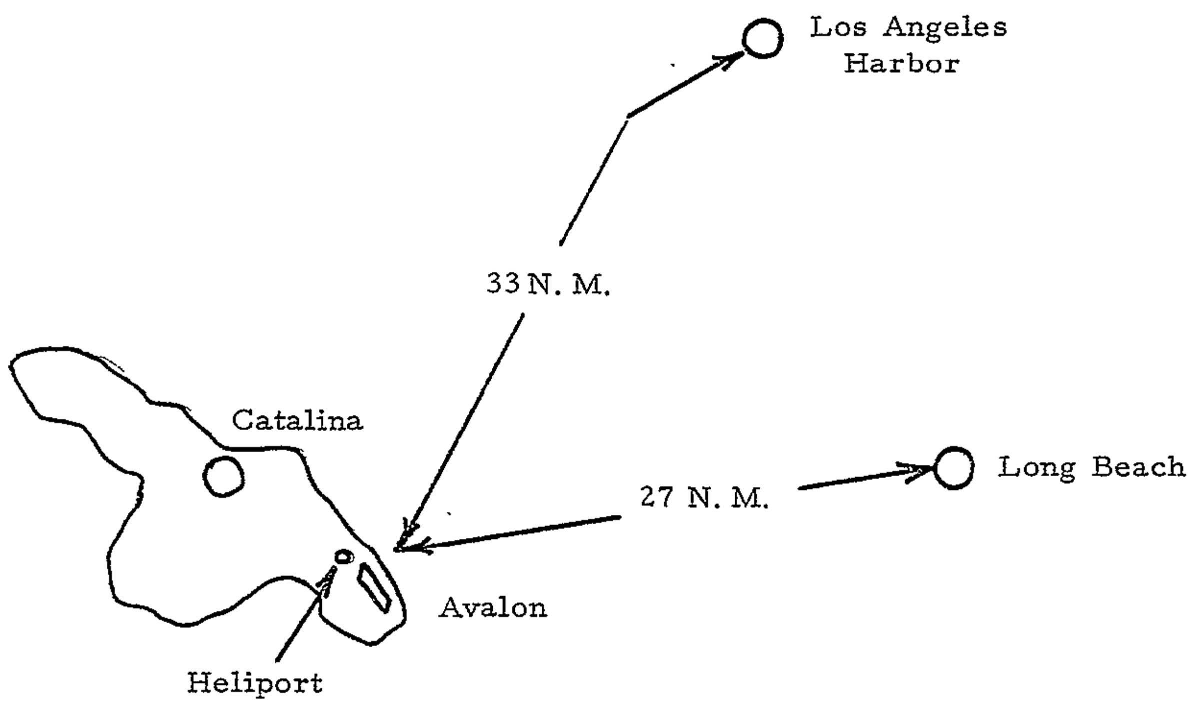


Figure A2-4
Catalina Airlines Route Structure

Operational Interview - Golden West Airlines

Newport Beach, California

Golden West Airlines is a commuter type short haul airline using the De Havilland Twin-Otter airplane to transport passengers in and out of Los Angeles International Airport. They operate these basic routes with five or six trips per day on each route;

Route 1	Los Angeles - Oxnard - Santa Barbara
Route 2	Los Angeles - Ontario - Riverside - Fullerton
Route 3	Los Angeles - Palmdale - Lancaster - Mojave Inyokern - Trona

The Average block time per leg is 25 minutes.

The airplane is configured for 19 passengers and two pilots. Golden West operates IFR at all times even though the weather conditions permit visual flight outside of the Los Angeles Basin 90% of the time. They fly below 10,000 feet on their routes and request to fly "Direct" whenever possible.

The avionics equipment in their airplanes is very simple: Twin VHF navigation receivers with DME, glide slope receivers, ADF, and Marker Beacon. They do not have a Flight Director or Autopilot.

The airplane is flown at 140 kts for climb cruise and descent. The transistion from cruise to the approach to Los Angeles International airport is made during the descent to the ILS glide path. They are required to mix in with the normal large jet traffic flow. The standard procedure is to maintain 140 kts until two miles from the outer marker where they start slowing to 125kts. The 125 kts is kept until about 500 feet. They then slow to 90 kts, extend the flaps and finally slow to landing speed.

Their terminal gates are on the very West end of the terminal complex. They plan to land long and make a quick turn off the runway near their gates. The outlying airports do not present any unusual problems for the airplanes.

Golden West doesn't attempt to operate STOL.

The two-man crew work load in the Los Angeles area is about the same as a turbo jet airplane crew work load during an instrument approach. The airline uses the Jeppeson approach plates. This operation does not require any special handling by ATC except fitting the 140 knot airplane into 160-180 knot traffic.

They do not exceed the 30° bank limit standard for airline operation. There isn't any pilot concern about maneuvering either on instruments or visual. The Twin-Otter is a stable airplane on an approach and landing. The airplane is speed stable. When the wing flaps are extended it becomes even more stable.

The wind correction used when gusts are reported is to add an airspeed increment equal to half the steady headwind component. The wing-down slip technique is used for cross winds.

. The minimums at Los Angles are 200-1/2 whereas at Santa Barbara they are 300-3/4. The NDB approach at Trona is 500-1.

This airline does not fly a curved path approach IFR. The visual 45 approach to Los Angeles is routinely used and a curved approach is flown into Santa Barbara. There is an area East of Santa Barbara airport that is very sensitive to any over-flight by an airplane. The local airport authority has established visual approach paths to the airport that avoid this area. The preferred path requires a 45° turn while descending from 1500 feet, which can be completed above 500 feet.

The Twin-Otter has excellent response to go-around power in event of a missed approach. The procedure is to advance the power to go-around level and retract the flaps to half. The airplane accelerates very quickly to 120 kts, then the flaps are fully retracted and climb power set. This usually occurs before any turn is required.

The standard SID's and STAR's for the Los Angeles area do not provide direct routing to the cities that Golden West services. Therefore, Golden West could benefit from the use of RNAV.

The high winds of the Antelope Valley (Palmdale, Lancaster) sometimes causes difficulty by limiting the visibility with blowing dust. Golden West usually suspends operations during these conditions. Most of the winds are prevailing Westerly and most of the runways are oriented so that large cross wind components generally do not exist.

Golden West has purchased two NORD Sky Vans to add to their fleet, so [illegible] the steady increase in passenger traffic in their market will not result in an increase in service frequency. The Sky Van will be operated with 49 passenger seats. One trip with this airplane will provide more seats than two trips with the Twin-Otter.

Golden West has experienced very good steady growth in their market in recent years and expects to add an airplane with double the capacity of the Sky Van to their fleet.

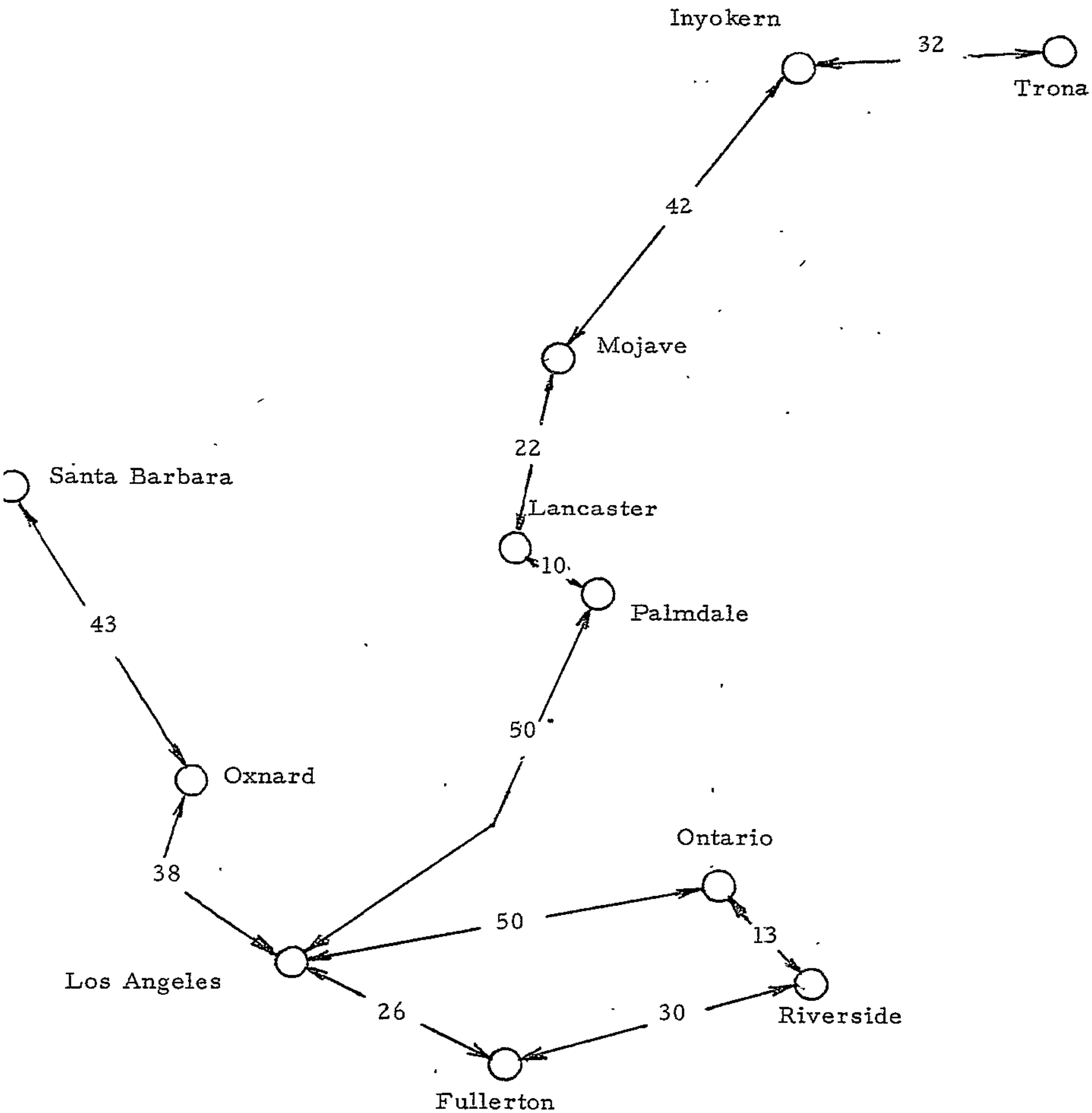


Figure A2-5
Golden West Airlines Route Structure

Operational Interview - Rocky Mountain Airways

Denver, Colorado January 4, 1977

Interview with Captain Eric Norton, Vice President of Flight Operations. (Captain Norton flies about 40 hrs. of regular schedule per month.)

This airline operates primarily at high altitude airports. The Route Structure is:

Denver to Leadville (11, 400 ft.)
Denver to Eagle
Denver to Colorado Springs
Denver to Aspen
Aspen to Steamboat Springs
Aspen to Leadville

The airplane they use is the De Havilland Twin Otter. It is operated with 2 pilots and carries 19 passengers. They keep the seats at 19 so they do not have to use flight attendants.

The airplane maximum take-off gross weight is 12, 500 lbs. It cruises at 125 kts IAS at 16, 000 feet MSL. Transistion from enroute to landing starts by slowing to 105 kts and extending 10^{o} of flaps. Full flaps are extended when the airspeed is below 95 kts. Their take-off distance at Denver (5330' MSL) is about 1, 500 feet at maximum gross weight. Their landing distance is normally 2, 000 feet. When they operate in a STOL configuration, the landing roll is about 800 feet. The normal final approach is flown at 82 kts. The STOL approach is flown at 66 kts. The STOL configuration is full flaps, flat pitch on propellers, flight idle and the low airspeed.

This airline operates IFR all the time, in and out of Denver. There is no approach control at the high-mountain airports of Aspen, Steamboat Springs, Eagle, or Leadville. They maintain contact with Denver Center during transistion from cruise to approach then change to their company while on the approach. These mountain airports do not have full time control towers. During actual IFR, they follow direct routes from Denver to Kremling VOR, then by VOR radial to the non-directional beacons that they own and maintain at each of the destinations. The NDB at Aspen serves as the point of descent on the MLS 6^{o} approach. Using the 6^{o} glide slope requires a special procedure for the Twin-Otter. The airplane is aligned with the localizer, slowed to 90 kts and full flaps extended. Power is set for airspeed of 82 kts. The descent is made on the glideslope with the airspeed stabilized. Stabilizing on the 6° G/S offers a problem to the pilots unless the airplane is slow and in the landing flap configuration prior to descent. There are mountain winds and wind shears with which to contend. On occasion the initial approach altitude will be 13,000 ft. MSL and the wind is a 70 knot tail wind. The rate of descent under these conditons can be as high as 1800 ft/min. The airplane is unpressurized and this causes some passenger discomfort. The occasional 20° nose down pitch attitude also causes some adverse passenger comment. On occasion the pilot will explain the problems to the passengers and it becomes a choice of accepting these conditions or returning to Denver. The decision is usually resolved in an acceptance of the steep approach. This is a mountain airport that requires landing to be one direction and take-offs in the opposite direction.

The cockpit work load for 2 pilots when making an IFR approach to Aspen or Steamboat Springs is the same as that during large jet IFR approaches. The airplane has 2 VHF navigation radios for basic positioning, 2 ADF receivers for approach alignment, and 1 MLS receiver. IFR approaches at Denver use the standard ILS and the pilots very often use the Sperry Flight Director for this approach. The MLS approach is raw data only because the Flight Director is not capable of using this signal. None of the airplanes have an autopilot.

The Denver terminal area transistions are standard ATC procedures. The airline uses the Jeppeson approach plates. During VFR conditions at Denver, approach control usually keeps the airplane high until close in and then directs a descend on a 4-5° visual path and a landing near the runway turn off point. They spend a very short time on final approach and the runway.

The bank angles during IFR do not cause any concern because all turns are completed well above the ground. VFR the airplane responds very well, without any special pilot skill required to fly steep close in turns.

The MLS localizer and glideslope captures and transistion is no problem to the pilots, if the procedure for the steep approach is followed. The pilots usually use 10° of flaps and 85 kts for standard ILS. The Flight Director capture and transistion is a simple nose down command on capture which washes out and becomes a deviation error correction command.

Speed control can be a problem on the 6° glideslope because of the flight idle minimum power limits. If airspeed is high and the flaps are not positioned to 30° prior to descent then a tail wind can cause an airspeed problem and a corresponding high rate of descent problem. Nearly every approach into Aspen has some sort of windshear situation that requires pilot attention.

If strong headwinds are present, the airplane is flown with 20° or 10° of flaps and power and extra airspeed is carried. Crosswind landings are made with the wing down method and the airplane does this very well.

The airline does not fly any curved path approaches nor do they want to.

The go-around criteria is different for each airport. Aspen is the most restrictive. The minimums there are 1300-2. This is a limit imposed by the airplanes go-around performance and ability to clear the mountainous terrain. The procedure is to apply take-off power, move flaps to 10° and make a climbing 30° bank turn around to the NDB. At Steamboat Springs the minimums are 600-1 with exactly the same avionics equipment and reliability. The difference being that the terrain clearance is not as much a problem as it is at Aspen. At Denver the minimums are 200-1/2. The pilots express confidence in flying down to the minimums to which they are trained, 100-1/4.

Their systems, the standard ILS, VOR, NDB and MLS all accomodate pilot errors very well. Corrections do not appear to require any special technique or procedure.

The mountain traffic when actual IFR exists usually produces a saturation of the system because of the radar limitations in the mountains and the use of company communications. When VFR exists the system operates very well even though the same routes and transistions are used.

This airline is not familiar with RNAV. They do not think it could be justified in their operations as they fly direct in most instances and the short legs between airports are essentially pre-programmed because of the consistancy in flying them day after day.

They get very few route changes enroute. All the routes are worked out with the FAA and ATC center, and well coordinated prior to their use.

The airline does not expect their block times to be affected by the use of RNAV. Like most airlines they would not want to add anything to their operations that would not pay for itself.

The special weather conditions encountered in their operations are those associated with the Rocky Mountains. High winds, wind shear, turbulance, rain, snow and icing conditions in the air and on the surface are prevalent. The airplane accomodates 30 kts of cross wind without difficulty. Some of the short runways, like Steamboat Springs, are not used if they have runway clutter.

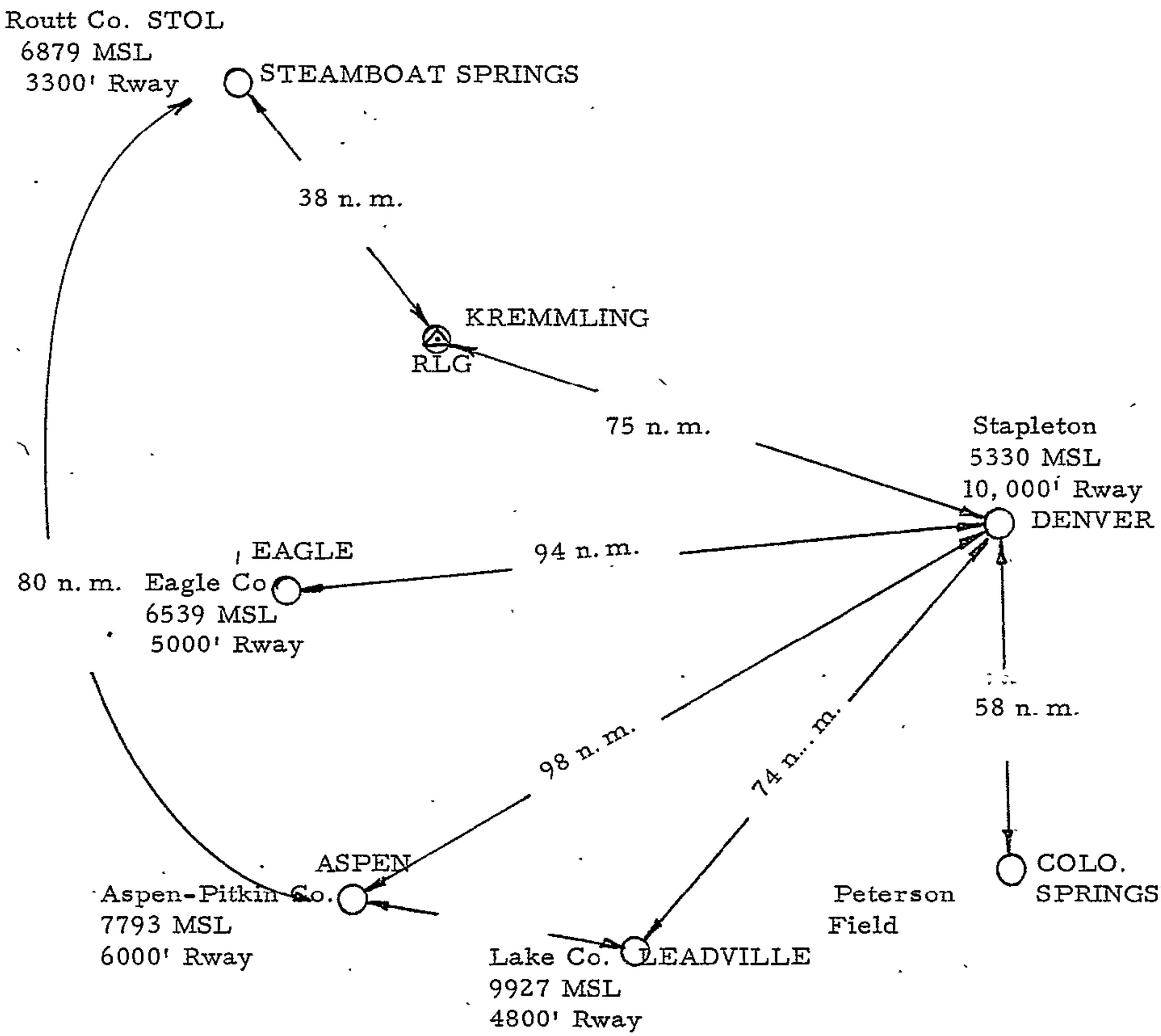


Figure A2-6
Rocky Mountain Airways Route Structure

OPERATIONAL INTERVIEW
Salt Lake City, Utah

SUN VALLEY KEY AIRLINES
February 10, 1977

Interview with Marty Ellison and John Jason, pilots.

The chief pilot of the airline is Laray Newby. Sun Valley Key Airlines is a short haul commuter airline flying between Slat Lake City and Sun Valley, Idaho and between Boise and Sun Valley. The company usually flies three round trips per day from Salt Lake City and two per day from Boise. This schedule is altered by traffic demands. The company will operate more frequently on weekends and will stand down rather than fly empty flights.

The Company uses several different types of airplanes. They have one Twin-Otter and three Convair 440's, that are used to fly the "scheduled" routes. Their pilots stay qualified in both airplanes. They have a MU-2 Metsubishi that is in use as a hospital litter carrier, and they operate a Piper Navajo for charter work.

Key Airlines standard procedure is to fly the Twin-Otter at maximum cruise. They maintain maximum cruise power and indicate 140 kts enroute. This speed is maintained until about 3 miles out on final approach. From this point the pilots use idle thrust, establish a 3° glideslope and slow to flap speed. The flaps are extended as speed permits and power is added to maintain 80 kts to runway threshold.

The approach into Sun Valley is flown VFR from an airways intersection 20 miles south of Freidman airport. The airport minimums for normal operations are 1700 feet higher than the minimums required at the 20 mile final fix. The landing is always from a straight-in VFR approach. The approach and landing at the Salt Lake Airport is much different. Salt Lake approach control usually keeps the flight at 8000 feet MSL until they are about 8 miles north of the airport. If the weather is VFR and landing is on runway 34 a descent is made onto a downwind leg. From here a standard base and final is flown. If the landing is on runway 16, they start down immediately making a straight-in 4° glidepath on final. The Convair 440 has a difficult time with a 4° glidepath approach, so the pilots anticipate the problem and slow up, extend partial flaps prior to starting down. They extend the gear and full flaps and descend with idle thrust to make the landing. Landing long is not a problem with the short landing roll of the Convair.

The airline operates with a two-man crew in all of their airplanes and the cockpit work load is like most two-pilot operations.

The airplanes have dual VHF navigation radios and low frequency ADF. The Twin-Otter has a King RNAV set that can provide one-waypoint navigation. The pilots refer to it as a VOR offset because they fly into the waypoint and away from it like they do a VOR station. The RNAV route they fly is not certified so it is only flown during VFR conditions. It serves to keep the route straight and shortens the normal route by several miles.

The pilots expressed an interest in a MLS approach into Friedman. It was their opinion that if there were such an approach, the Twin-Otter could fly two-way traffic at Sun Valley. A 6^{o} G/S would provide proper clearance for an approach and landing to the south and the missed approach could fly up the 6^{o} glideslope on the opposite runway. This would permit a much lower landing minimums at Sun Valley.

The pilots have no difficulty with required bank angles on any of the approaches they fly. The only approach requiring 30^{o} bank is when landing VFR at SLC on runway 34.

The airplanes do not have a Flight Director, therefore all ILS approaches are raw data. The ILS intercept, capture, transition, and tracking by both airplanes is standard. Speed control with the Convair is difficult when a steep approach is required.

The normal winds encountered do not cause any difficulty. Cross-wind limitations of the airplanes do not restrict flight operations. At Sun Valley the Convair has to take-off to the south in order to clear the mountains. The 10 kt tail-wind limitation on the Convair often causes a delay in departure.

This airline does not fly any curved path approaches.

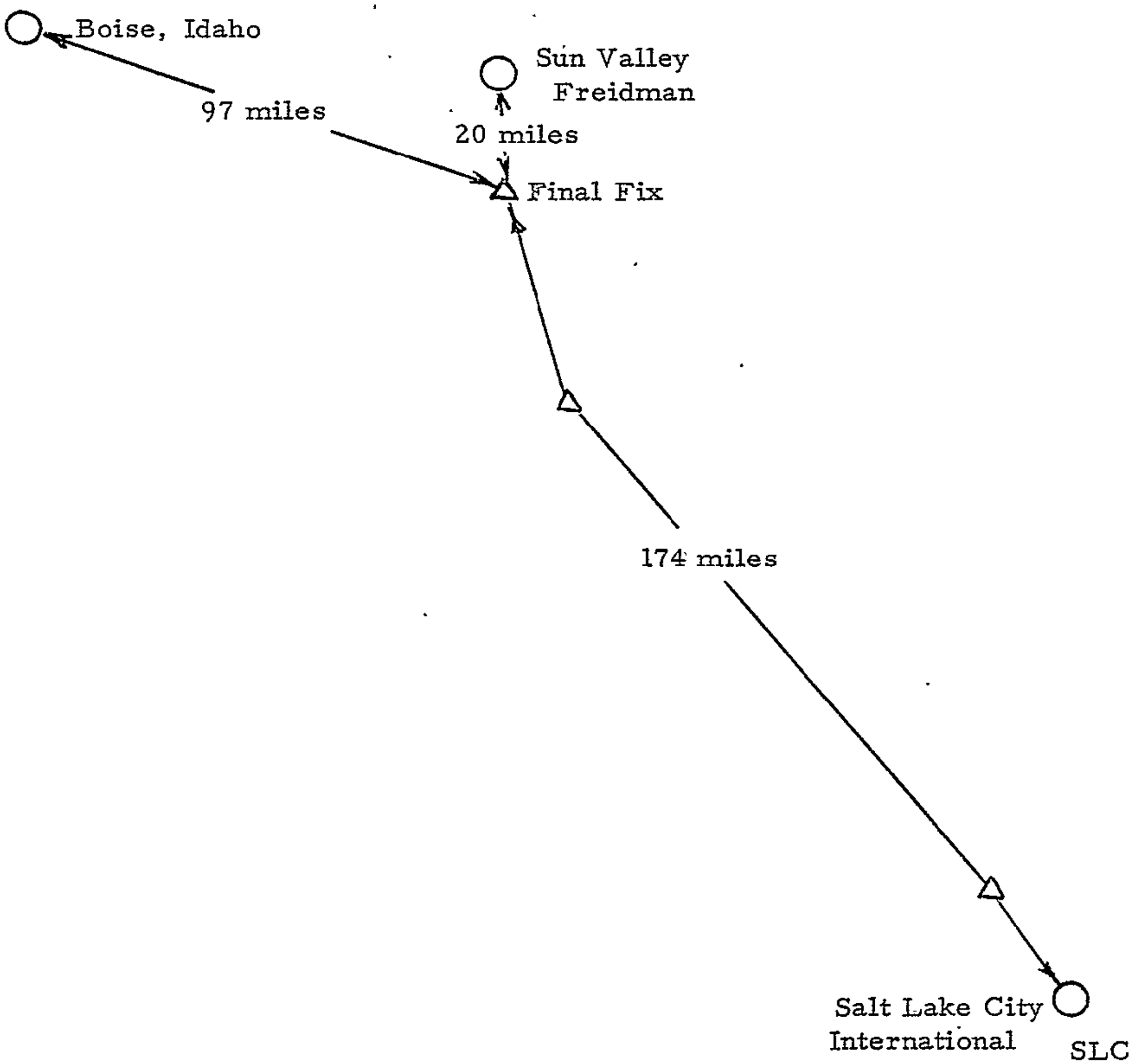


Figure A2-7
Sun Valley Key Airlines Route Structure

Operational Interview - SWIFT AIRE of San Luis Obispo

San Francisco, California June 1977

Chief Pilot and Vice President of Flight Operations is Richard Dixon. Swift Aire is a short haul commuter type airline flying between its home base of San Luis Obispo and San Francisco and Los Angeles. They have recently expanded their operations which now includes eleven cities with applications to add two more. Their direct non-stop authority is limited to San Luis Obispo, Fresno, San Francisco, San Jose, Los Angeles, Santa Maria, and Sacramento-Fresno. They connect several of the other cities to each of these; Paso Robles, Visalia, Bakersfield, and Modesto. Their longest route leg is 146 nautical miles.

In March 1977 they added the NORD 262 Airplane to their fleet of De Havilland Herron's. They will have three NORD 262 airplanes and seven Herrons. The NORD 262 is a twin turbo-prop, high wing airplane with the gear retractable into fuselage pods. Swift Aire operates the airplane with two pilots, 29 passenger seats and one flight attendant.

Swift Aire's operation of the NORD 262 is in the low altitude route structure, usually at 10,000 feet MSL or lower and at 200 knots IAS. At this flight condition the transistion from enroute to the terminal area is the same as large turbo-jet airplanes. The transistion to the San Francisco Airport runway 28 is usually a radar vector to the Visual Bridge Approach. The pilots can keep 180 knots IAS on a 3° glideslope below 1500 feet AFL and then slow to landing speed by 500 feet AFL. The transistion to the Los Angeles Airport runways 24 or 25 is usually a vector to the 45° Visual Approach. The approach speed is kept up between 160 and 180 knots until established on the 3° final approach course. The drag of the propellers at flight idle is sufficient to aid in deceleration to landing speeds while on a 3° glide path. Flight operations during low ceiling and visibility conditions is similar to large turbo-jet airplanes so the NORD 262 fits right in with the normal traffic flow. Visual approach to the smaller airports are very similar to light airplane traffic. If an approach requires a 180° turn to final, the downwind leg is usually flown at 1200 ft., gear and approach flaps extended with airspeed about 125 kts. The final turn is completed at 500 ft. above touchdown zone, and landing flaps extended on short final. There is no attempt to fly a noise abatement or a curved path approach. All IFR approaches are the standard ILS or VOR approaches published for the terminal airports. There is no attempt to operate the airplane in a STOL configuration. The shortest runway used is 4000 ft. in length and it is adequate for normal operation. Ground idle is almost reverse thrust. The blade angle is about-1.15°.

The pilot technique during high winds and cross wind is to add airspeed equal to half the wind component and use the wing down, side slip metered for landing in a cross wind. The airplane has a high frequency structural response to turbulance and thus a "bumpy" ride in turbulance.

The airplane has good performance for takeoff and landing and go-around performance has been good in training.

The flight and navigation equipment is standard IFR with a Flight Director and Autopilot. The use of RNAV equipment could help their operation as they would then be able to plan direct routes instead of requesting direct on most flights. Ninety percent of their operation is in visual condition of more than 3 miles. There is no history of any special operations except the local VFR operations sometimes encountered at Modesto or Fresno.

One of the reasons Swift Aire selected the NORD 262 is the good efficiency of ground operations. It is the plan to replace the De Havilland Herron airplanes with the NORD 262 and also add a 50 passenger airplane to their higher passenger density routes.

The ground operation of the airplane is very simple. Turning off the runway the pilot shuts down the #1 engine, upon reaching the blocks, the Flight Attendant opens the rear door on the left side, (the bottom half of the door is the entry stairs) and disembarks the terminating passengers. The ground attendant opens the front door on the left side and unloads the baggage from the baggage area between the passenger cabin and the cockpit. The ticket agent sends the embarking passengers out for the flight attendant to load. The ground attendant loads the new baggage, closes the front door, closes the rear door, pulls the chocks, and signals the pilot to taxi. The pilot starts the #1 engine while taxiing and the flight is on the way. The airplane ground time at some of the connecting stations is only five minutes.

The flight operations have now expanded so that a Herron airplane is laid over at Bakersfield, Modesto and Sacramento for the early morning flights. The NORD always departs from San Luis Obispo in the morning and arrives back there at night. The flight crew change and refueling is also accomplished at San Luis Obispo.

The airline gets good utilization of the NORD-262 by planning 15 trip legs per day and using two flight crews.

A typical operational week day is scheduled as follows:

Flight	Departs	Scheduled Time to	On Ground
	0600		Crew in Dispatch Office
191	0645 SBP	1:05 SJC	First Flight of the day
191	0755 SJC	0:20 SFO	25 min.
192	0840 SFO	0:20 SJC	10 min.
192	0910 SJC	0:50 PRB	5 min.
192	1005 PRB	0:20 SBP	25 min. Home Base
192	1050 SBP	0:15 SMX	10 min.
192	1115 SMX	0:50 LAX	25 min.
193	1230 SBP	0:50 SMX	5 min.
	1300		New crew arrives
193	1325 SMX	0:15 SBP	20 min. Home Base Refuel and Crew change
193	1400 SBP	1:00 SFO	30 min.
	1400		Old crew leaves
194	1530 SFO	0:20 SJC	10 min.
194	1600 SJC	1:05 SBP	25 min. Home Base
194	1730 SBP	0:15 SMX	10 min.
194	1755 SMX	0:50 LAX	1:15
195	2000 LAX	1:00 SBP	Terminates for the day

This schedule results in the following utilization per week day schedule. Saturdays and Sundays are scheduled differently.

15:30 Air Crew Time

10:35 Airplane Block Time

8:50 Airplane Air Time

3:35 Airplane Ground Time

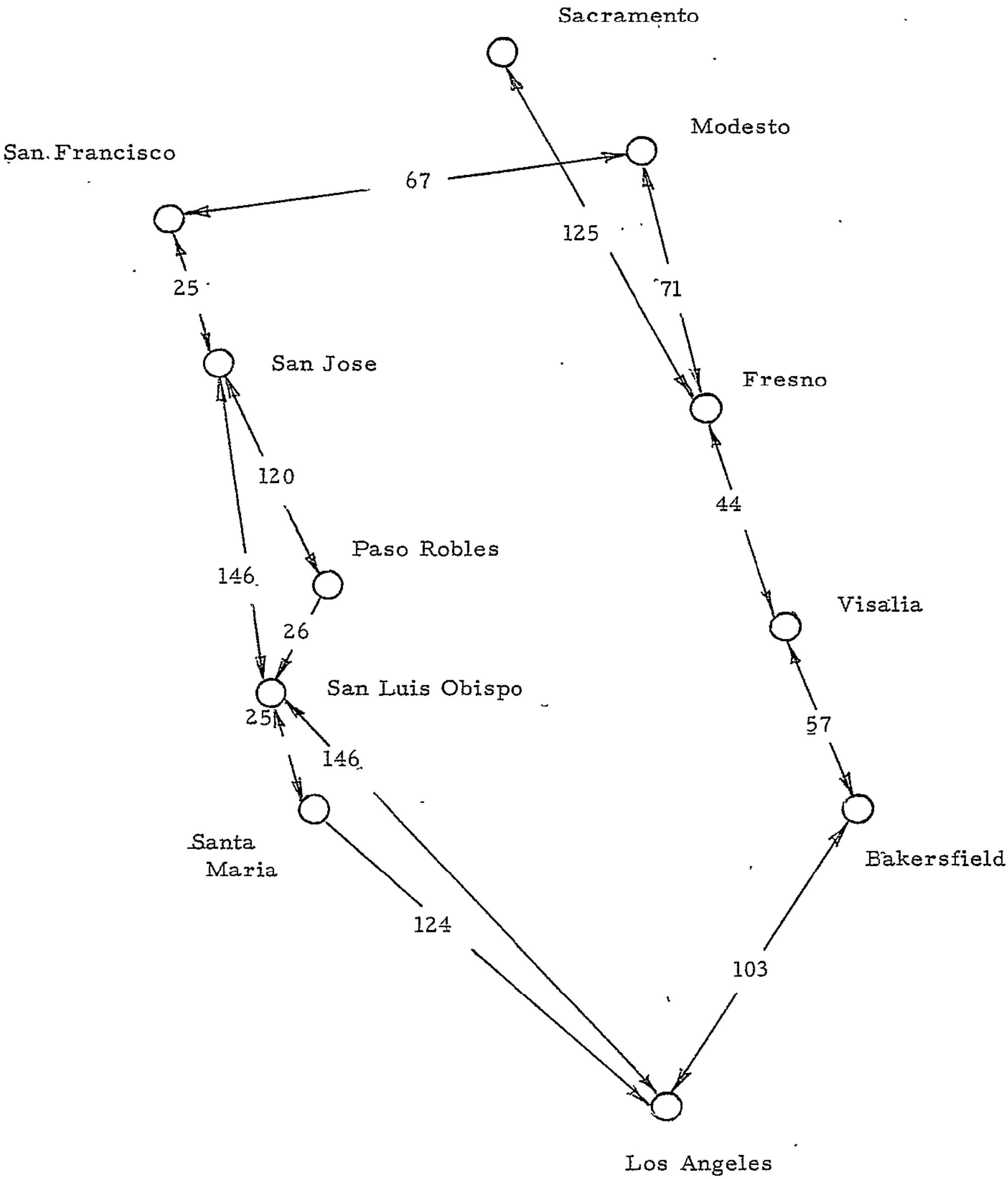


Figure A2-8
Swift Aire Route Structure

Operational Interview - STOLAIR of Santa Rosa

San Francisco, California December 21, 1976

Interview with Dave Ferguson, Pilot

Chief Pilot of Airline is Neal Mahall. STOLAIR Airline is a short haul commuter airline flying between home base of Santa Rosa, San Francisco, Concord and NAPA, all of which are located in California. Their longest flight leg is 25 minutes, block time.

The airplane they use is the BRITTEN-NORMAN ISLANDER. This airplane has twin reciprocating engines, high wing, fixed gear, and a maximum gross take-off weight of 6600 lbs.. It has a maximum of 10 seats and usually operates with a pilot and 9 passengers. When the normal routes cannot be flown VFR-on-top or if the take off and destination airports are both reporting IFR then the operator puts on 2 pilots and operates under FAR part 135. This allows full IFR operation. Dave Ferguson had flown with a co-pilot only once in 1976.

The Islander Airplane cruises at 125 kts IAS at 3,000 feet MSL. The normal approach speed is 65 kts IAS. The speed for maximum flaps is 100 kts IAS. The airplane at maximum gross weight will use 1,000 feet for takeoff and 1,400 feet for landing.

The transistion from cruise to landing at San Francisco has been coordinated between ATC - approach control - tower and STOLAIR. The path is usually VFR and under the normal ILS traffic. The airplane is flown at 130 kts down to 500 feet, 90°perpendicular to the ILS final heading. A visual turn onto final holding that speed until about 10 feet above the runway. The power is reduced and the airplane slows to 100 kts. The flaps are extended as the airplane slows to 65 kts. A landing is usually made about 4,000 feet down the runway. The landing at Concord, California is a standard light airplane traffic pattern. The downwind leg is entered at 125 kts IAS - airplane slowed to 100 kts flaps extended to 25° on base leg the airspeed is slowed to 65 kts and the flaps extended to 56°. The downwind to base turn uses 30° bank, the final turn 15°-20°. The 65 kts is maintained on a 4-5° glide angle to threshold where the throttles are closed and the airplane decel erated to 55 kts for flare and landing.

There is no bank angle or turn rate limit during IFR or VFR. Most IFR operations fit right in with regular airline traffic. The pilots keep their speed up as high as possible and fly above the glideslope to avoid turbulance from the airplane ahead.

The cockpit work load is not excessive during normal opertions and can be handled by a one-man crew. During IFR low visibility operations, the addition of a co-pilot keeps the work load down.

The airline operates with minimum avionics. They do not have a Flight Director or Autopilot. The airplanes are equipped with 2 VHF navigation radios and an ADF receiver. They fly direct routes in the low altitude structure and present no apparent problem for ATC or the approach controllers.

The airline uses the standard Jeppeson approach plates and follow standard procedures for light airplanes.

The IFR approaches flown are the same as those flown by the large jet airplanes. The bank angles thus required do not present any difficulty. The low altitude close in turns are all flown VFR.

Flying the standard ILS presents no problem and it is usually flown in excess of 100 kts. The pilot has no difficulty in slowing the airplane once visual contact with the runway is made. The airplane tracks the localizer and glideslope very well. The two 260 HP lycoming engines respond very rapidly to pilot input. The high drag configuration with the flaps down makes this airplane very speed stable. The only poor handling quality of the airplane is the over sensitive elevator trim. This makes small trim adjustments during an IFR approach difficult.

The flight techniques used during high winds is to delay use of the flaps. Very little airspeed is added for head or cross wind corrections. They set the prop control at 2,000 RPM and carry power. The cross wind technique is to lower a wing and keep the airplane straight with rudder. They do not attempt to fly a curved path approach. They do make low final turns, sometimes well below 500 feet.

The airplane response to a go-around is adequate for all of the airports in which they operate. The prop control is preset at 2,000 RPM, so with a power application the airplane immediately accelerates. The flaps are positioned to 25° and upon attaining 100 kts the flaps are brought up.

This airline uses basic navigation data without a flight director or autopilot during normal operation. There is no need for precision flying in cruise or on approach. The pilots maintain heading, airspeed and altitude very loosely and because they have a small pilot group there isn't any attempt at formal standardization.

The operation fits in well with ATC. The pilots contact ATC on the normal frequencies. The controllers are used to working the flights regularly and there are no apparent major problems. Their routes in and out of San Francisco airport were decided upon by trial and error. ATC moved them around until there was a minimum of conflict. This airline does not have any RNAV equipment but has considered using it. RNAV could shorten their routes and they would like to have a standard route that could be pre-programmed. This airline seldom gets any route alterations from ATC now that their routes are established. RNAV would probably just simplify their navigation and not change their current block times.

The airline usually operates VFR or VFR on top. If the approach minimums are below 300-1 they usually wait for the weather to raise. They do use special VFR with visibilities as low as 3/4 mile at some airports like Concord. They seldom have to use a special runway because of wind. If the large jet airplanes are operating on a particular runway--so do they. Runway clutter has never been a problem and operating in heavy rain with standing water on the runway does not present a problem.

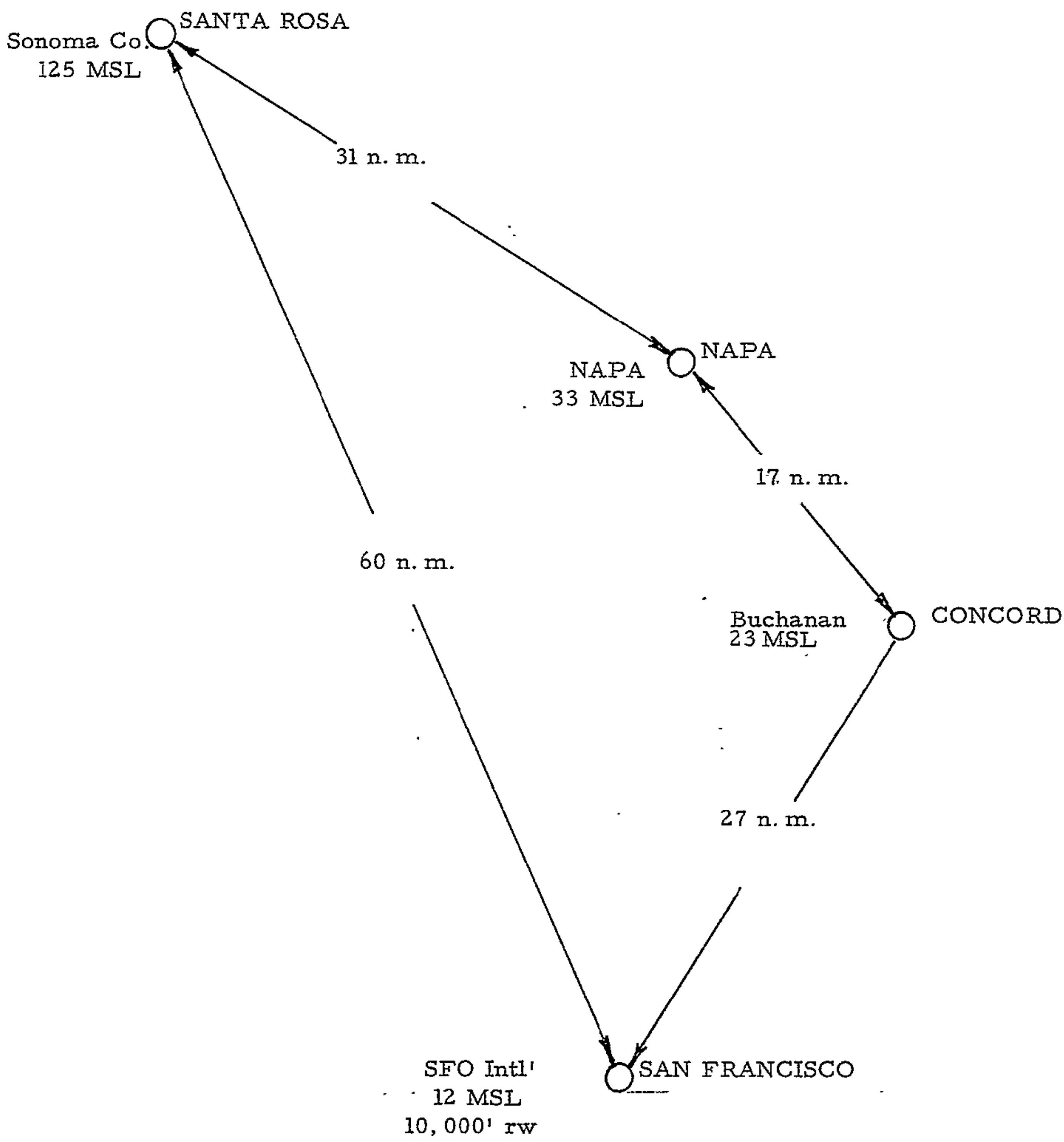


Figure A2-9
STOLAIR Route Structure

APPENDIX 2

SECTION 3

SHORT HAUL TRANSPORT

All levels of the air transportation industry is engaged in short haul transportation. A centrally located city in a high density population center like Chicago will have large trunk airlines as well as a lot of regional airlines carrying high volume short haul passengers on routes from 100 to 700 miles. A hub city like Denver that has a much lower density population area but with a lot of small out lying cities around it has trunk carriers, large regional carriers, several local carriers and a lot of small commuter carriers. The aircarriers presently serving Denver are:

Trunk Carriers
Braniff
Continental
Delta
Mexicana
Trans World
United
Western

Regional Carriers
Frontier
North Central
Ozark
Texas International

Local Carriers
Aspen
Rocky Mountain

Small Commuter Carriers
Air Nebraska
Air Midwest
Intermountain
Pioneer
Rapid Air
Star
Stearling
Trans-American
Trans-Mountain
Trans-Western
U.S. Aviation
Valley

Thus from this airport, Stapleton International, there are airplanes as large as the B-747, operated by the free world's largest airline, and and as small as the Piper Lance, operated by Valley Airpark., (this commuter airline has only two airplanes which are a 6 place single engine, 160 knot airplane) operating from the same terminal.

Most large volume air traffic airports have long parallel runways to accomodate the heavy traffic. Stapleton has a similar set of runways for the trunk and regional carrier traffic. The small commuter and other light airplane traffic is accomodated by a third parallel runway that has been added to the field. A short runway north of the long east/west ones, and a short runway between the long north/south ones. These additional runways are too short for an airplane the size of a DC-9 or B-737 except at very light gross weights, but very adequately accomodate the airplanes used by the local and commuter carriers. The light airplanes are able to enter the terminal area through special lanes in the terminal control area that avoid the large departing and arriving airplanes. During visual flight conditions the light airplanes usually follow a curved descending path to a short final approach. The wings level segment is usually a 3-4 degree slope from 300 feet to touchdown. Rocky Mountain Airways Twin-otter airplanes have been observed making a 6-7 degree curved descent onto these runways.

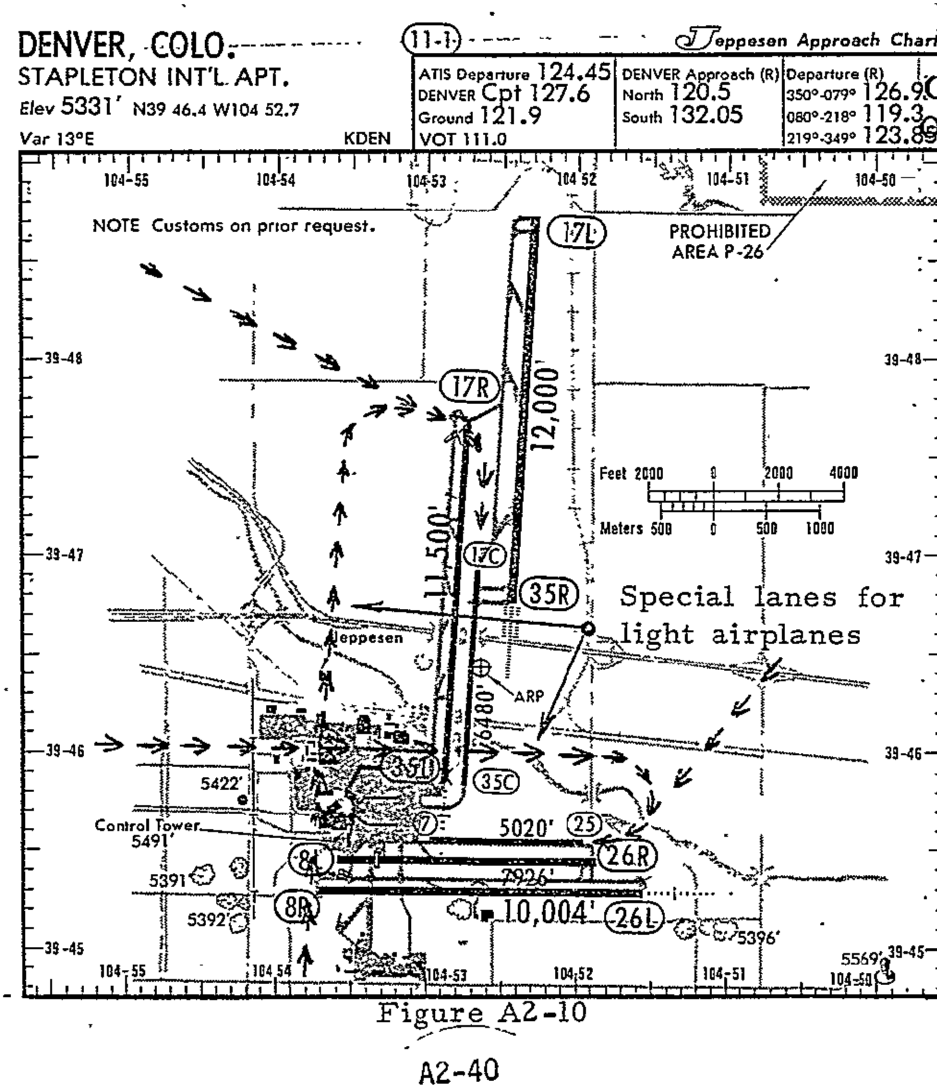


Figure A2-10

When low ceiling or low visibility flight conditions exist or during night hours the light airplanes have to follow the big airplanes and use the long parallel runways. The inability of the light airplanes to use a curved path approach to the short runways during actual instrument weather conditions contributes to the saturation and congestion of the terminal area.

The small commuter and local carriers do not carry the majority of the short haul passengers. The airplanes they use have small passenger capacity (3-19). The larger short haul airplanes like the DC-9 or B-737 which carry from 90 to 110 passengers, are used by the Regional and some Trunk carriers to move the vast majority of the short haul traffic.

Examining some typical short haul routes upon which Piedmont, Frontier, and United Airlines operate the B-737 shows a great variety of flight leg length.

<u>Piedmont</u>

Route 1.	Chicago to Myrtle Beach	691 N. M.
	Myrtle Beach to Richmond	246 N. M.
	Richmond to Fayetteville	174 N. M.
Route 2.	Chicago to Norfolk	648 N. M.
	Norfolk to Richmond	80 N. M.

<u>Frontier Airlines</u>

Route 1.	Denver to Rapid City	265 N. M.
	Rapid City to Minot	301 N. M.
	Minot to Bismark	100 N. M.

<u>United Airlines</u>

Route 1.	San Francisco to Eugene	403 N. M.
	Eugene to Portland	105 N. M.
Route 2.	San Francisco to Modesto	88 N. M.
	Modesto to Stockton	20 N. M.
	Stockton to San Francisco	72 N. M.

The reasons for using the B-737 in this way vary. United uses the airplane on its short routes because it's the smallest airplane it has and it can easily operate from the 6000 foot runways found at the low altitude airports. Frontier uses the airplane on its long routes because it is the largest airplane it has, and they put more powerful engines on it to accomodate the short runways they must operate from. A reason common to both airlines is that an airplane with about 100 passenger seats is needed to carry the traffic in their short haul market. So United will use the airplane on a 400 mile leg or a 70 mile leg and likewise Frontier will use their biggest airplane on short 40 mile leg in order to accomodate the traffic.

One airline commented that their future short haul requirements would be for a quiet airplane with 200 seats that could operate from a 4000 foot runway.

The operation of United Airlines Route 2 shown above is typical of the B-737 as a short haul transport. On this particular day, Flight 958 departed Gate 7 at San Francisco International Airport at 0703. The wind in the northern California area was generally out of the west. Take off was from runway 1 R. The flight crew and flight attendants out numbered the passengers 6-4. The airplane made its initial climb of 15°to 7000 MSL. It passed the Oakland VOR, made a 15°bank turn to heading of 060°, and several moments later passed Altamont intersection headed toward Modesto. Moments later the airplane was at 1600 feet, and slowed to 160 knots with flaps at 5° and the landing gear extended. The airplane is now on a downwind leg for runway 28R at Modesto. One mile east of touchdown flaps are extended to 25°, 30°bank for a 180° turn to final. Airspeed slows to 140 kts, the flaps are extended to 30°, further slowing to 125 kts, the 180° turn is completed at 500 feet MSL, flaps extend to 40° and a short final approach at 120 kts is terminated in a smooth landing. The engines are shut down at Modesto terminal at 0729, for a flight length from gate to gate of 26 minutes.

The second leg departed Modesto terminal 30 minutes late because of surfacing equipment on Stockton's runway. This is typical of the smaller airport operations. The 63 passengers boarded, were in the air just a few minutes. The airplane only has to climb to 2000 feet MSL, turn, using a 10° bank, about 40°right, intercept the 29R localizer course of Stockton, use a 15°bank to turn inbound, and its on final approach. Departure from Modesto at 0830, arrival at Stockton terminal at 0844, a 14 minute trip.

Thirty more passengers boarded the airplane at Stockton, and 10 minutes later at 0854 Flight 976 departed for San Francisco. This leg required a 30° bank turn to intercept the 229° radial of the Stockton VOR, and a climb to 7000 feet MSL. Upon reaching Cedes intersection, the flight receives a radar vector to the Visual Bridge Approach for runway 28L at San Francisco. This approach requires the airplane to proceed inbound on the 095° radial of the San Francisco VOR, cross the 18 mile DME at 6000 feet, the 13 mile DME at 4300 feet, the 6 mile DME at 1900 feet, and maintain a 3° descent to the runway from that last point. Arrival at gate 3 of San Francisco International Airport is at 0924 following a thirty minute flight. All 93 passengers disembark, most of them to continue on other flights.

Thus the B-737 is used as a short haul transport and is pressed to its aerodynamic limits to be able to fly the short routes in minimum time. The maneuvering and navigation ability of this airplane is excellent and not limiting in the least for the short haul. The ability of the pilots to slow the airplane after the quick turn onto the Stockton ILS and during the San Francisco Visual Bridge Approach is a challenge. Any delay in reducing power or adding drag can result in a high final approach speed with low power and an extended landing roll. It is fortunate that the Stockton and San Francisco runways are long enough to allow for some abuses of these approaches. Shorter runways do not permit such a luxury so the airplane has to be flown slower and preparations made for the approach much sooner. The takeoff and landing performance appears to be the limiting characteristic for this short haul transport.